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A REINFORCED-CONCRETE BAND STAND.

By W. F. CREIGHTON.*

In Centennial Park at Nashville, Tenn., there has recently been built a reinforced-concrete band stand which is probably unique in its design and which, on account of the double curved surfaces, presented some difficult features of construction. The general appearance of the stand is quite well illustrated in the half-tone in Fig. 1 and the details of design can be readily comprehended from the drawing reproduced in Fig. 2. The bars used to reinforce the stem are tied at the bottom to a 1 × 3-in. circular iron band and are held in place at the narrow part of the stem by a similar band and at the outer edge of the ceiling by a hooked connection with the reinforcing rods of the roof. As the distance between the stem reinforcing rods was so great where they branch out at the perimeter of the ceiling, intermediate rods were placed between them and run, near the upper plane of the ceiling, to a third circular 1 × 3-in. band. These alternate rods are marked "ceiling" and "main stem" on the plan in Fig. 2. The upper part, that is the roof, was reinforced with circumferential rods and with wire cloth of 4-in. mesh and No. 10 gage. Rain water is prevented from running down the stem by the eave drip, which was made by laying a ½-in. round on the forms before the concrete was poured; this device has answered the purpose fairly well, though it would have been better if the size of the half round had been larger or deeper. Light is provided by incandescent bulbs spaced every 2 ft. 6 ins. around the edge of the ceiling.

The concrete was composed of one part cement, two parts limestone dust and four parts 1½-in. to ⅝-in. broken stone. The concrete was mixed by hand and raised in an elevator frame by mule power. The wheelbarrows were loaded and raised direct to a platform at the top and rolled on runways to place. The elevator frame was constructed by building two 4 × 4-in. pieces spaced 4 ft. apart and cross braced at top and bottom. A snatch block was attached to the top piece, and when a barrow was ready to be raised, a short piece of rope about four feet long with rings on each end was placed on the handles of the barrow and the main fall, which had a hook on the end, was run under it and hooked to the wheel of the barrow. The mule was then started and when the barrow was loosened at the top the short piece was dropped, an empty barrow lowered on the fall line and everything was ready below to raise another barrow. The process was continuous and concrete was disposed of as it was mixed.

FIG. 1. A REINFORCED-CONCRETE BAND STAND IN CENTENNIAL PARK, NASHVILLE, TENN.

(Designed by E. C. Lewis, M. Am. Soc. C. E. Built by Foster & Creighton Co.)

Some difficulty was anticipated in building the surface forms at the small part of the stem on account of the double curve, and as it would have been difficult to build it of wood, No. 20 sheet steel was selected. The sheets were hammered to fit the curve in the shop and nailed direct to the circular ribs and extended from the floor to the edge of the roof with the sheets laid to break joint. The steel forms were supported by ten vertical circular ribs made of 2-in. lumber to fit the 7 ft. 8 in. radius circle shown in Section HH, Fig. 2. At the upper part of these ribs the spreading of the radii brought the backing so far apart that intermediate cross ribs were introduced, giving an 18-in. sheet steel spacing.

In erecting these forms concrete was first laid to the level of the floor and the vertical reinforcing rods carried through the 1 × 3 in. band in the small part of the stem, continuing therefrom in a vertical line. The ribs were then erected and supported at the tangent point of the curve and at the outer edge by false work. The steel plates were then hammered on to the ribs. When this form was in correct position, vertical reinforcing rods were bent to their correct curve and fastened at the end of the ceiling. The work was built in three stages. After the excavation was completed to rock, the 12-in. pipe was erected and a hole filled with concrete to the surface of the ground; concrete for the stem and what might be called the ceiling was next poured, and the work was not stopped until it was complete, though it took 30 hours; it was not thought wise to stop this part, thereby making a joint in this section of the stand. The roof was then laid and finished by hand and the 12-in. pipe was filled. After the falsework was taken down the circular steps were built and the floor laid.

The stand was completed in August, 1907, and at the present time (May, 1908), no structural cracks have developed.

Eighty cubic yards of concrete were used and the following table shows the cost:

	Total Cost.	Cost per cu. yd.
Superintendence	$42.00	$0.53
Foreman	39.00	0.48
Labor—		
Mixing and placing	171.00	2.14
Bending and placing steel	40.00	.50
False work and wooden forms	113.90	1.43
Steel forms, labor and material	164.00	2.05
Furnishing and erecting 12-in. pipe	86.25	1.08
Unloading and hauling stone ½ mile	60.00	.75
Excavating	5.00	.06
2,500 ft. B. M. lumber and shop work	76.21	.96
Reinforcement, 5,500 lbs.	229.00	2.86
Stone, 80 cu. yds. at $1.10	88.00	1.10
Dust, 40 cu. yds., at $1.10	44.00	.55
Cement, 119 bbls., at $2.65	316.95	3.95
Finishing	12.00	.16
	$1,487.31	$18.59

The stand was designed by Maj. E. C. Lewis, M. Am. Soc. C. E., and erected by the Foster & Creighton Co. of Nashville, Tenn.

*With Foster & Creighton, Nos. 1-3 Berry Block, Nashville, Tenn.

CORROSION OF THE STEEL WATER SUPPLY CONDUIT AT ROCHESTER, N. Y.

By RICHARD H. GAINES.*

The water supply for domestic uses at Rochester is obtained from Hemlock Lake, about 29 miles south of the city. Tapped from the lake at an elevation of 386 ft. above the city level, the water is carried by gravity to the storage and distributing reservoirs by two separate pipe systems locally known as Conduit I. and Conduit II. These conduits were laid a short distance apart, and follow the natural undulations of the surface wherever the land lies below the hydraulic grade lines.

CONDUIT I.—The older of the two pipe systems, known as Conduit I., was constructed in 1873-4-5. The first section is about 10 miles long, extending northerly from the intake at Hemlock Lake, and consists of 36-in. wrought-iron pipe with cast-iron hubs and spigots, and poured-lead joints. The next section proceeding north about ⅓ of a mile, is also of wrought iron, 24 ins. in diameter, jointed in the same manner. The next section for a length of 5¾ miles is 24-in. cast-iron pipe and this is succeeded by 2⅝ miles of 24-in. wrought-iron pipe. The last 8¾ miles is again 24-in. cast-iron pipe. The last section ends in Mt. Hope distributing reservoir, the conduit on the way connecting at Rush with a storage reservoir.

There is little to be said about the cast-iron sections of this pipe. The important fact to be remembered is that no rust holes have appeared in this part of the conduit. During 32 years of service, leaks have occurred from time to time at lead joints, and tubercles forming on the interior have reduced the carrying capacity, but otherwise it has given no trouble.

The first two sections of Conduit I. were constructed of riveted plates of wrought iron, 4½ ft. long and from 3/16 to ¼ in. in thickness. Prior to laying this pipe in the earth, it received a coating by the usual dipping process in an equal mixture of Trinidad asphalt and coal-tar pitch.

Conduit I., as a whole, has given excellent service from the beginning. In 1894, Chief Engineer Kuichling stated that there had been but one leak from corrosion, and not one cent had been expended for repairs during the 19 years the pipe had been in operation. A few small leaks in the wrought-iron sections (less than 10 in number) were discovered at intervals and repaired between 1894 and 1904, but none have been reported since the latter year. According to recent reports from Rochester, Conduit I. remains generally in good condition after more than 32 years' service. During this long interval, the pipe has been under the constant surveillance of overseers and such trouble as supervened from corrosion has been of a trifling character.

It will be shown later that the soil in which this pipe was laid, and other circumstances surrounding it, were anything but favorable to its preservation. A better example could hardly be found of the durability of wrought iron under trying conditions.

CONDUIT II.—Fourteen years after Conduit I. went into service, it became evident that the supply of water furnished would be insufficient for the increasing population of Rochester. The overtaxed condition of the storage reservoirs in 1888 made it manifest that a new supply must be provided. Investigations and reports by engineers led to the decision in 1890 to lay a new main from Hemlock Lake to the city. Conduit II., which was subsequently built, contains, apart from its magnitude, many points of unusual interest worth relating.

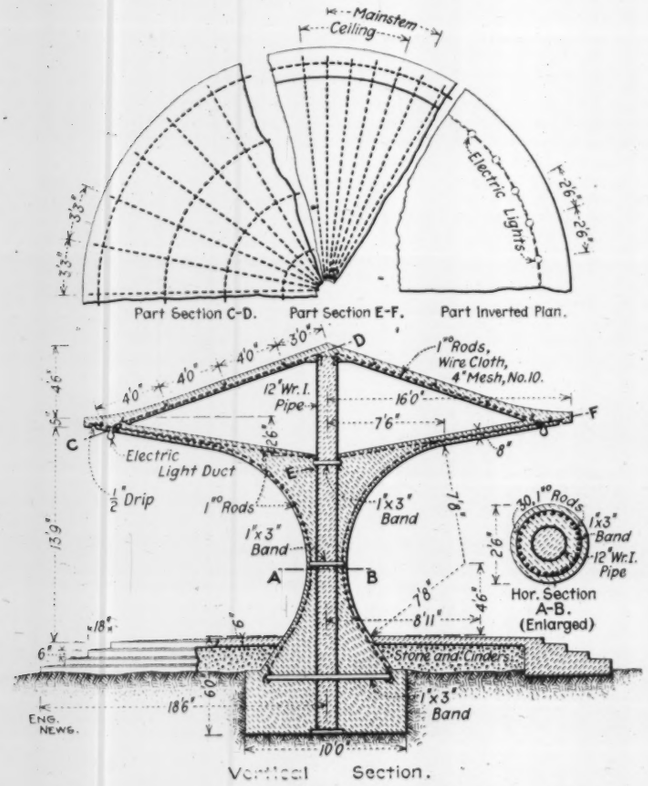

FIG. 2. DETAILS OF REINFORCED-CONCRETE BAND STAND.

About this time, 1888-90, the use of steel for large water pipe was beginning to be adopted. Not until a few years before had steel become a commercial article on a scale to be available for work of this character. It was claimed that iron refined by the new process was practically free from carbon and cinder, and combined all the best qualities of wrought iron with the added strength of steel. In this state, it was thought to be especially adapted to the manufacture of water pipe, although little was known of its durability. These statements are intended not so much to show how the use of steel pipe began, as to call attention to the very brief period that has elapsed since its advent—less than 20 years.

The East Jersey Water Co. was one of the pioneers in the use of large steel pipe, letting a contract in 1890 for a 21-mile line of 48-in., and a 5-mile line of 36-in., riveted steel water supply conduit for Newark, N. J. Other water companies, and several cities were contemplating the use of steel. No particular warning seems to have been given by the experts consulted of the danger or possibility of deterioration.

The foregoing facts, and particularly the relative cheapness of steel, led the authorities at Rochester to decide upon this material for the new main. The final contract was let in January, 1893. The conduit as completed two years later will be described in some detail. The data for the following description were collected during a recent visit to Rochester for a personal inspection of an uncovered portion of the conduit; from special reports of Chief Engineer Kuichling, published in Engineering News; and from reports of the Rochester Department of Public Works.

An aqueduct consisting of a brick conduit of horseshoe-shaped cross section, 2½ miles long, terminates in an overflow chamber 34 ft. long, the north end of which forms the beginning of a 38-in. pipe conduit about 26¼ miles [illegible] length, connecting with the Rush storage r[illegible]oir on the way, and ending at the Mount [illegible]e distributing reservoir. About 26 miles of [illegible] length is 38-in. (inside diameter) steel pipe, [illegible] ¼ mile is 36-in. cast-iron pipe.

The main pipe conduit was constru[illegible] of soft open-hearth steel plates, nearly 7 ft. [illegible]g. and ¼ to ⅜ in. thick, riveted as cylindrical [illegible]de and outside courses, alternating, and form[illegible] a tight fit with each other before the protect[illegible]oating was applied. Soft steel rivets of the [illegible] composition as the plates were used for ri[illegible]g.

The specifications for all material [illegible] in the construction of this pipe were drawn [illegible] great care and after exhaustive study by E[illegible] Kuichling, C. E., the Chief Engineer in cha[illegible] of the work. The specifications called for [illegible] open-hearth steel containing not over 0.6% [illegible]ganese and 0.06% phosphorus, with a tensile [illegible]rength of between 55,000 and 65,000 lbs., and [illegible] elastic limit of not less than 30,000 lbs. The th[illegible]knesses of the plates were varied according to the pressure to which they would be subject[illegible] in the line of the conduit. For pressures due to static head of 120 ft., or less, ¼-in. thickness was demanded; with a static head ranging fr[illegible] 120 to 200 ft., 5/16 in.; and for over 200 ft. head, ⅜ in. All plates less than 95% of the required thickness were rejected without appeal.

The steel pipe for the southern half of the conduit was supplied by the East Jersey Pipe Co., of Paterson, N. J., and that for the northern half by the Rochester Bridge & Iron Works. The steel plates used at Paterson were made by the Carnegie Steel Co., and those from the Rochester Shops by the Paxton Rolling Mill at Harrisburg. Before delivery from the mills, the plates were inspected and approved by Booth, Garret & Blair, the well-known metallurgical chemists.

THE METHODS OF COATING.—Numerous experiments with different kinds of asphalt, and other substances, were made under the direction of the engineer-in-charge during the years immediately preceding the construction of the conduit. All the materials, however, that were subjected to a practical test gave more or less unsatisfactory results.

After the decision was reached to use steel in the new work, the best experts were consulted concerning the question of coatings. Prof. A. H. Sabin of New York was engaged to conduct a series of investigations, with the hope of developing a method that would be both practical and permanent. Before Prof. Sabin's experiments were completed, the work had to be proceeded with.

The first section of the pipe, 7½ miles in length, nearest the lake, was given a coating of California asphalt by the East Jersey Pipe Co., similar to that applied to the large steel conduit just completed for the water supply of Newark, N. J. The method used in applying the coating was as follows: After a pipe was riveted and calked, it was thoroughly cleaned, heated in an oven to about 300° F., and then dipped horizontally in a large tank containing the hot coating material (kept at an average temperature around 350° F.) where it was allowed to remain for such time as would suffice for the temperature of the metal to become the same as that of the mixture. The pipe was then removed from the bath, the surplus coating allowed to drip off, and it was then placed on skids outside where the material was left to harden.

The results at first appeared to be satisfactory, but after the pipes had been exposed to the air for several weeks, the high gloss gradually disappeared, leading to the inference that the substance was undergoing a slow change. In fact, the coating showed signs of disintegration before the pipe was put into the trenches. Moreover, it failed in adhering tightly to the metal, and the contractors were subjected to much expense in painting over many spots and larger areas from which the coating had scaled off during the transportation and handling.

For the next 5½-mile section of the conduit, directions were given the East Jersey Pipe Co. to substitute for the California asphalt a mixture of refined Trinidad asphalt and the best grade

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of coal tar pitch in equal proportions, thereby producing the same coating as had been applied to the old conduit, and which in that case had apparently proved durable. Although this mixture was more satisfactory on the whole than the California asphalt, it left much to be desired in toughness and adhesion to the steel. The East Jersey Pipe Co. had now about completed their portion of the work.

Meanwhile, promising results obtained by Prof. Sabin from experiments with a japan process led to the adoption of this method for the northern half of the pipe. The Rochester Bridge & Iron Co. applied the process under the supervision of Prof. Sabin at a plant especially provided near the shops. Sections of the pipe 27½ ft. long were first heated in an oven to a temperature of 300° F., then dipped vertically in the hot coating mixture at the same temperature. Upon removal from the bath, the pipe was allowed to drain and then transferred to a large brick oven, kept at a fairly even temperature of about 500° F., where it remained 10 hours, after which it was ready for use. The materials, the precise composition of which was not stated, were all prepared on the spot. Baked japans, however, are usually made from linseed oil, and asphalt as a base, mixed with more or less copal resins, and are thinned with turpentine. The preliminary heating of the pipe before immersion in the dip assures its adhesion and impermeability. Although more expensive than the other methods, it was claimed that the japan coating was elastic, impervious to atmospheric influences, running water, dilute acids or alkalies, and owing to the nature of the ingredients electrically passive, except to currents of high voltage.

After the conduit was completed, the chief engineer expressed great satisfaction with the japan coating, stating that it was superior in all respects to those which were applied to the southern half of the pipe. For a time, it was generally considered that baked japan coatings left but little if any room for improvement in the coating of water mains.

VIEW ON LINE OF ROCHESTER WATER SUPPLY CONDUIT, SHOWING PROCESS OF TRENCHING, CLEANING CONDUIT AND PAINTING.

Shortly after the completion of the work, and years before any trouble developed, the chief engineer, in a report, expressed apprehension about the southern half of the conduit, stating that the coating used to protect the pipe there had failed to adhere tightly to the metal. Moreover, it was said that in spite of all precautions there were numerous abrasions both during transportation and in the field, i. e., while getting the sections of the pipe riveted together in the trenches. A preparation called "P. & B. Paint" was selected for repairing the bare spots, which was applied with a brush to the cold pipe in the field. The defects of this remedy, and the material, will be referred to later.

Abrasions in the Sabin coating were repaired with an air-drying varnish, similar in composition to the japan mixture used at the shops.

GENERAL DATA.—The pipe was generally furnished in sections 27½ ft. in length, consisting of four courses riveted together in the shops, and having all seams thoroughly calked both inside and outside. After the pipes had been coated and delivered along the route of the conduit, two lengths were riveted together upon the surface of the ground, thus forming a section about 54.5 ft. in length. These sections were then rolled in succession by a large number of men upon suitable timbers laid across the trench from where they were lowered into position by derricks.

It was contemplated that the pipe conduit should be a continuous, riveted tube throughout its entire length, without expansion joints or other mechanical devices for compensating changes in length caused by variations in temperature. By this continuity, such changes are prevented from manifesting themselves and are replaced by internal stresses in the metal, which are far within its elastic limit for the range of temperature encountered in the work. Motion was prevented by bedding the ends of the pipe in large masses of masonry.

As stated at the outset, the steel conduit goes through the same territory as Conduit I., the distance apart varying from 25 ft. to an extreme of about one mile. It is therefore subject to practically the same external physical conditions. The greater portion of Conduit II. is laid through fine farming country and, as in the case of Conduit I., this pipe conforms to the general undulations of the land through which it passes.

Conduit II. went into service as soon as completed in 1894. During the succeeding years it was thoroughly inspected outside every summer, and once or twice examined inside. From 1894 to 1900 a few insignificant leaks due to imperfect calking were found. In a 200-ft. section of the interior of the northern portion, a negligible quantity of tuberculation was all that was seen. To all appearances, the conduit had remained in good condition during the first six years after its completion.

RUST LEAKS.—In 1900 two small leaks were discovered near the southern end in the part of the pipe coated with California asphalt, which were caused by corrosion of the steel plates. In 1901 thirteen rust leaks occurred in this part of the conduit, three of which were in a single plate. At this point, the pipe was uncovered for a short distance north and south, when several plates were discovered that were badly corroded and the coating in poor condition. Numerous pits were found in the steel varying in size from ⅛-in. to 1 in. across, and in some cases ⅛-in. deep. It was easy to see that if let alone, these pits would in time develop into rust holes.

At first, the corrosion seemed to be more or less confined to about 2,000 ft. of Section I. of the southern division of the conduit, and was believed to be due to some local conditions. The reason first assigned was that the pipe plates there were probably of poorer quality than on the rest of the line. But later, as the trouble began to spread, it was deemed advisable to begin a careful investigation of all sections of the conduit. Test holes were dug, and trenches several hundred feet long were excavated here and there all along the line of the pipe. Throughout the southern half of the conduit where asphalt and coal tar pitch had been used, the coating was found to be in poor condition, and many plates were pitted. Wherever the pipe was found to be corroded, it was scraped, painted and occasional leaks were repaired.

The inside of the conduit was also examined near the south end of the line for a distance of 250 ft. Considerable tuberculation was found, some sheets having as many as 100 tubercles, on the removal of which pits were revealed. No leaks, however, have been observed as coming through from pits on the interior of the pipe. Repairs to the pipe were made by closing the hole with a wooden plug, then covering it with a patch of sheet lead, and a steel patch, held in place by heavy iron bands or clamps passing around the pipe, after which the outside edges of the lead were calked.

The reports contain no reference to corrosion in the northern half of the conduit until 1903, when four rust leaks appeared in a small section of pipe laid through a swampy area. At the end of 1906, only fourteen leaks in all had been discovered in the half of the conduit coated by the Sabin japan process, and these occurred in a section of the pipe less than ⅔ of a mile in length, in wet, low ground, mainly a cedar swamp.

Since the trouble made its appearance in 1900, the whole line of the conduit has been under the rigid scrutiny of overseers stationed on the different sections.

The following table gives a list of leaks caused by corrosion in the steel pipe, with the divisions and years in which they occurred:

Year	Rust holes.	Section.
1900	2	I.
1901	13	I.
1902	5	I.
1903	18	4 in Sec. I. 8 in Sec. II. 6 in Sec. III.
1904	38	19 in Sec. I. 19 in Sec. II. 0 in Sec. III.
1905	34	25 in Sec. I. 6 in Sec. II. 3 in Sec. III.
1906	33	20 in Sec. I. 8 in Sec. II. 5 in Sec. III.
1907 Incomplete	21	
Total No. of leaks..	164	

Sec. I. coated with California asphalt; Sec. II. coated with Trinidad asphalt and coal tar pitch; Sec. III. received the Sabin japan coating.

METHOD OF COMBATING THE CORROSION.—As soon as the full gravity of the trouble was realized, steps were taken to arrest or prevent further damage by recoating the pipe. The work has been chiefly done during the summer months each year, the following method being pursued: Wherever the pitting or corrosion is active, the pipe is uncovered in short sections and scraped clean. The pits are thoroughly cleaned out with a sharp instrument and afterwards heated sufficiently with a blow-lamp to dehydrate any rust left. As soon as the pipe has been made ready in this way, it is given several successive coatings of waterproof paint applied with a brush; first a coat of Superior Graphite Paint No. 501, which is allowed to dry; then a coat of Superior Graphite Paint No. 106, which is allowed to dry; two coats of Mineral Rubber Paint G. B. are then applied at short intervals, and as soon as the paint is dry the trench is refilled. Canvas awnings are provided to protect the exposed pipe from the weather. The portions of the conduit affected by corrosion will continue to be recoated in this manner as rapidly as practical, thus anticipating leaks in many cases, and providing better protection to the metal in the danger districts.

The method of repairing the smaller leaks has been previously described. When, however, the patch has to cover a considerable area due to a series of holes or pitted places which are so continuous as to preclude the use of individual small patches, or where the plate is so weakened as to need a continuous cover plate of considerable size, an elastic cement sold under the trade name of "Pyrocenit" and manufactured at Paterson, N. J., has been successfully used. This material is furnished in two parts, a powder and a liquid, which are intimately mixed to form a stiff paste. It expands slightly on setting, is water-tight and adheres closely to the metal, which it is also said to preserve.

OBSERVATIONS AT ROCHESTER.—While the work of recoating the pipe was in progress during the past summer, and in response to an opportunity afforded through the courtesy of City Engineer Edwin A. Fisher, the writer was directed to accompany T. C. Atwood, Assistant Engineer, to Rochester for an examination of an uncovered portion of Conduit II., where a typical case of corrosion might be seen. On the 14th of June, with the cooperation of John F. Skinner, Principal Assistant Engineer in Charge, we were shown in an open meadow, two miles southeast of Honeyoe Falls, and about 10 miles north of the Hemlock Lake, an exposed section of the pipe several hundred feet in length. The conditions existing in this section were supposed to be fairly representative of the un-recoated portion of the southern half of the conduit. The writer got into the trench and examined the pipe with care for more than 300 ft. On close inspection it was found that about four-fifths of the plates were still in good condition. On the remaining one-fifth, however, the destructive process of corrosion was active, and the effect was very apparent. In many of the plates, the corrosion was in its initial stages, while in others it was far advanced with multiple pits, and the occasional ominous evidence of a perforation that had been repaired with a patch in the manner previously described.

THE CORROSION CENTERS.—The pittings or rust deposits were small raised surfaces nearly circular in shape, although some of them had an elongated, irregular outline. The soft rust at these spots could be readily cut away with a knife. Wherever the rust was all taken out, a clean, round hole with characteristic sharp edges would be found, from ⅛-in. to ⅞-in. in diameter, and 1-16-in. to ¼-in deep. The holes looked as though the metal had been drilled out with a sharp instrument. Some of the plates presented the appearance of having been pock-pitted, or attacked by a corroding disease.

INSIDE THE PIPE.—No opportunity was presented of seeing the condition of the interior of the pipe at this time. The engineer in charge, who had made previous examinations, reported numerous tubercles on the inside of the pipe which covered pits shaped in cross-section like the cross-section of a saucer; the outside pits were more like the cross-section of a cup. The inside corrosion does not appear to be of a serious nature in any event. Whereas, 164 leaks have occurred due to outside corrosion, not one has yet been discovered as proceeding from the inside. This last is probably due to the fact that on the inside of the pipe there is a constant current of water flowing, and the electrical conditions there are uniform. Iron or steel exposed intermittently to the action of water corrodes much faster than when immersed in water all the time.

THE CONDITION OF THE COATING.—The uncovered portion of the pipe examined on the 14th day of June had received as a protective coating nearly 14 years previously, a mixture of Trinidad asphalt and coal tar pitch. The condition in which the coating was found, varied in different sections according to the thickness of the original covering, and the amount of water in the surrounding soil. Many surfaces were found (especially in springy or wet areas) on which oxidation and decay had finished their changes, and the coating had completely lost its efficiency. Other sections of the pipe, laid in soil that was more porous and that had probably retained a thicker covering after leaving the vats, had undergone considerable change, yet the process of oxidation had not destroyed the coating. These irregularities can be ascribed not only to inherent defects in the material itself, but to the sheer impossibility of securing anything approaching a uniform thickness of coating on the metal by the method used for its application.

STUDY OF THE CAUSES OF CORROSION.—When the trouble first appeared it was supposed to be possibly due to stray currents, although no car lines or other artificial sources of electricity were near. The electrician in charge of the municipal laboratory at Rochester made a careful survey along the whole line of the conduit. No measurable current could be found with the millivoltmeter from outside sources, even where the pittings were worst. All the galvanometric readings thus made gave negative results. The explanation was therefore to be sought elsewhere.

As a preliminary step in the studies to ascertain the cause of corrosion in the steel conduit, the writer collected samples of soil, drain water, steel, rust from the pittings, and samples of the coating for examination or analyses at the laboratory.

THE SOIL.—The underlying rocks of the particular area visited were observed to be shales, with some limestone outcropping here and there. The lands generally throughout the district are upland meadows and apparently fertile. No unusual conditions occur other than ordinarily seen in open country, miles away from town or village. The soil surrounding the pipe where uncovered was quite uniform in character—a heavy clay usually light in color, rarely red, and almost saturated with water wherever the pitting was worst. No evidence was observed of any special local corrosive influences, such as gases in the earth, acidic rocks, or their decomposition products.

A complete analysis was made of the sample of the soil taken from the trench, within a few inches of a badly corroded section of the pipe, with the following result:

Silica, SiO_2	50.42
Alumina, Al_2O_3	15.65
Lime, CaO	12.36
Magnesia, MgO	3.64
Iron Oxide, Fe_2O_3	1.71
Manganese Oxide, MnO	.55
Potassium Oxide, K_2O	1.04
Sodium Oxide, Na_2O	.47
Sulphur Trioxide, SO_3	.35
Loss on ignition (chiefly water of hydration)	14.13
	100.32

No unusual ingredient was revealed in the soil by this analysis. The water extract from an infusion of a portion of the sample gave a neutral reaction with the most delicate tests, indicating the absence of any abnormal acidity or alkalinity.

The mere chemical composition of a soil will not always indicate its corrosive character, although necessary to be determined, because the earth from local causes may be impregnated with substances almost unknown in the pure soil. The chief value of chemical analysis is in detecting the presence of certain soluble salts, which, if present, are decidedly corrosive. Especially is this true of the chlorides of the alkalies or alkaline earth metals which induce chemical action catalytically, and moreover afford a ready medium for electrolytic conductivity.

Extraction by infusion with distilled water of several samples of soil collected from the trench, in close proximity to corroded plates gave an average of about 1% of soluble material. The solids thus dissolved were found on qualitative analysis to consist chiefly of sulphates and chlorides of lime, magnesia, soda and potash. The part played by these strong electrolytes in the corrosion of the pipe will be referred to later.

GROUND WATER.—Samples of water were collected from under the pipe where corrosion was active, and also from a surface drain near by. These samples were found to contain an unusual quantity of both chlorine and free carbonic acid. The presence of certain organic matter, however, as well as phosphates, indicated human contamination, and thus no useful deduction could be made from the analyses.

COMPOSITION OF THE STEEL.—The specifications for the Rochester conduit, as stated previously, called for a soft, low carbon steel. Two samples of this steel were procured through the assistance of John F. Skinner, which gave the following results on analysis:

No. 1—Drilled from Unused Plate.

	%
Total Carbon	0.13
Silicon	0.13
Manganese	0.34
Sulphur	0.04
Phosphorus	0.011

No. 2.—Clippings from Pipe.

	%
Total Carbon	0.15
Silicon	0.10
Manganese	0.36
Sulphur	0.05
Phosphorus	0.009

The feature of these results is the low content of impurities. It is difficult to see how much segregation could take place in a steel as good as that shown by the analyses.

THE RUST.—An average sample collected from a number of the pittings or deposits was analyzed with the following result:

	%
Metallic iron { Ferric	31.17
Metallic iron { Ferrous	4.55
Carbon (by combustion)	0.27
Carbon Dioxide	2.88
Water { Hydration	17.92
Water { Moisture	22.80
From which the following composition is calculated:	
Ferrous Carbonate, $FeCO_3$	5.56
Ferrous Oxide, FeO	2.40
*Other Iron Oxides and Hydrates	68.97
Carbon	0.27
Moisture	22.80
	100.00

*There is no definite hydrate of iron of the form $Fe_2O_3 \cdot xH_2O$. The ratio of Fe_2O_3 to H_2O is a variable one and may be anything, according to circumstances. The normal hydrates are derived from the oxides of ferrous salts.

Several samples of the rust were carefully examined, both macroscopically and microscopically, for any enclosed particles that might have been the cause of local action. The results, however, were negative. Qualitative analyses were also made of other samples of rust cut out of pits in the pipe, but nothing could be detected besides hydrated oxides of iron, a small amount of ferrous carbonate and a trace of organic matter.

THE COATING.—A sample of the coating in its semi-oxidized state was scraped from the pipe for examination. This specimen gave on analysis a bitumen content of 65.21%. An effort was made to determine if the decomposition products of the coating were corrosive in action on the pipe. Several samples were collected near corroded spots, and afterwards extracted with warm distilled water at the laboratory. The extracts gave a neutral reaction, proving that none of the trouble had proceeded from this source.

THE RESULTS OF THE EXAMINATION.—The cause of corrosion in the steel conduit cannot be accounted for by any single circumstance. The survey for outside currents (stray currents), the character of the soil, the water draining away from near the pipe, the composition of the steel, the contents of the rust deposits, the coating and its decomposition products,—none of these sources when studied singly, offered a satisfactory explanation for the trouble. After a careful survey of every factor that may have played any part, either singly or combined, the conclusion was reached that the corrosion resulted rather from a combination of physical conditions than from causes that were chemical. Immediately after examining the steel pipe, the writer made this note: "On the spot, it looks as though the damage is due to defects in the coating, and minute physical irregularities in the plates." If to these two causes be added water-logged soils in contact with the pipe, the explanation of the trouble is at hand.

The portion of the steel pipe examined was laid in the earth at a depth of from four to five ft., a stratum in which a large amount of water is held by capillary attraction. This maximum water table, as it is called, is below the influence of surface evaporation in the clay soils, and above the influence of underground flow. The ground water in these places, from its long contact with the earth, becomes laden with soluble salts. Thus, a blanket of wet soil holds a jacket of electrolytes about the pipe, giving rise to all the conditions necessary for active corrosion, wherever the coating may have given way by abrasion or otherwise. The imperfect protection afforded by the coatings is self-evident, since corrosion could only occur where the metal was exposed to moisture or corrosive solutions. Inadequate protection must be admitted, therefore, as a prime cause. This of itself, however, is insufficient to account for the trouble, since plates were examined on which the coating had long since disintegrated, and no evidence of corrosion was apparent.

That soil influences played a leading part in the corrosion is obvious, from the fact that the damage to the pipe was confined to ground conditions of a definite character, i. e., soils in which was normally present an excessive amount of

water [illegible]e number of plates not visibly affected in th[illegible]et areas, however, proves that the trouble cannot be ascribed to the soil alone.

It is certain that local irregularities in the steel were a factor in the corrosion, because where subjected to precisely the same influences in the moist areas, some of the plates were corroded, and [illegible] were not. But the corrosion cannot be wholly charged to local irregularities of structure or composition in the corroded plates, for wherever the soils were of a porous or sandy nature, permitting excess of water to evaporate or simply unimpeded into the earth, the trouble does not occur at all.

The conclusion, therefore, follows that damage by corrosion in the steel conduit develops where three conditions meet, and co-exist: Ineffectual Coatings, Normally Wet Soils and Irregularities of Structure and Composition of Steel. These three influences in combination resulted in auto-electrolysis,—a word proposed by the writer for intense local action as manifested by pitting, in the absence of outside currents of electricity.

Since the causes of serious damage to the Rochester Conduit may, with slight modifications, exist anywhere, the conditions which led to trouble there will be discussed in a somewhat general manner.

DEFECTS OF BITUMEN COATINGS.—Under the trying conditions described, such coatings as were used for the southern half of the conduit (California asphalt and Trinidad asphalt and coal-tar pitch) afford protection to water pipe for only a brief period at best. It was inevitable that trouble would occur in the wet soils of the areas through which the pipe was laid. Official reports of the work at the time stated that much trouble was encountered with the asphalt coatings, which failed to adhere tightly to the metal, and besides numerous small abrasions were unavoidable. Some of this trouble was no doubt due to the imperfect contact between the coating and the steel. Apart from the fact that the melted bitumens are by nature capillary and bubbles which may be seen in a coated specimen under the microscope, and which no doubt are sources of weakness. Owing to the volatile hydrocarbons present, it is next to impossible to keep the melted pipe dip in a uniform state of mobility. So-called fluxes are poured into the vat from time to time to prevent the materials from becoming too immobile, but this remedy gives unsatisfactory results in practice, the melted liquid constantly varying in viscosity.

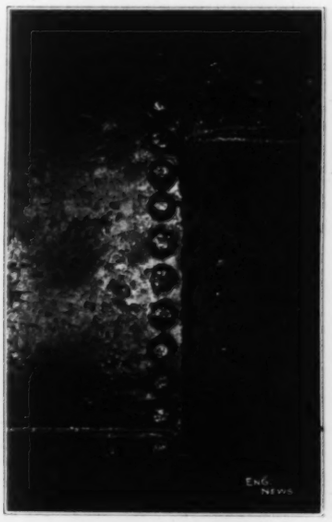
Perhaps the most serious imperfection connected with these coatings arises from the method of application. The pipe is heated to about 300° F. and then lowered either vertically or horizontally into a vat of melted pipe dip ranging in temperature from about twenty degrees below, to twenty degrees above 350° F. When slowly removed, the pipe is held in an inclined position above the vat until the excess coating drains away. Consequently, the coating may be from 1/4 to 3/8 in. thick at the lower end, and less than 1/32 in. at the upper, when the pipe is rolled out on the skids. Wherever the coating is of slight or inadequate thickness, it is easily ruptured by strains, and soon breaks down on exposure to adverse conditions.

The regulation of the temperature of the vat during the dipping process has apparently received insufficient attention. After the optimum dipping temperature has been ascertained by experiment, the range of temperature of the liquid bitumen should be kept at a minimum, or as nearly constant as possible. An important fact, that seems to have been overlooked in practice, is that the properties of the asphaltic compounds, like other amorphous bodies, undergo a steady change with rise of temperature. A difference of thirty or forty degrees may cause a decided difference in the character of the substances.

It is unknown to what extent bituminous pipe dips, as now applied hold in check corrosive influences in the soil. Unfortunately, the published data relating to the subject must be taken cum grano salis, since it has chiefly emanated from corporations engaged in exploiting some particular asphalt or other bituminous compound. It has been proved time and again that bitumen coatings will not prevent the corrosion of underground steel pipe where the soil conditions are really severe, i. e., if chlorides, acids, electric currents or any of the energetic rust formers are present along with excessive moisture. Pittings have been found in steel plates where the coating was apparently in a fair state of preservation, which demonstrates that the coating was neither proof against moisture nor the passage of currents from the pipe into the ground, causing electrolysis.

A high United States Government authority, after years of study and observation of these materials, recently told the writer that he had come to look upon all bituminous coatings as mere makeshifts, and of doubtful advantage. This view may be regarded as extreme, yet from the nature of the materials, there is reason to believe that this cheap method of coating cannot inhibit corrosion long. After application, the bituminous compounds undergo progressive molecular changes, lose elastic quality, become brittle, and, owing to the high expansion coefficient of steel, in time form a network of cracks through which moisture attacks the metal. Laboratory tests with small coated specimens kept in contact with water in glass jars proved that some of the asphaltic compounds break down and disintegrate in a few months, Trinidad asphalt especially, was shown to be quickly attacked by water, and it is no longer used for waterproofing. The tests demonstrated that there was considerable difference in the durability of the products, but no chemical method has so far been devised for recognizing the inferior materials. Some of the compounds are manufactured from "blown oil," to which has been admixed a variable quantity of refined native bitumen. The usual chemical and physical analyses do not reveal this fact, however, nor do they afford any reliable means of judging of the relative value of the different brands. Practical tests alone can determine their durability.

THE METHOD OF REPAIRING THE COATINGS.—The breaks in the coatings or abraded spots on the steel pipe were recoated with P. and B. paint, a material which is prepared by dissolving a mixture of California residual pitch and maltha in carbon disulphide. When spread upon a cold surface, the volatile ingredient which gives this paint flexibility is absorbed by air and water. The earthy constituent alone is left, and this being without coherence, falls off, leaving the spot bare as before. Every such surface readily becomes the center of chemical and electrical activity when in contact with soil water.



SOME TYPICAL EXAMPLES OF PITTING ON THE ROCHESTER STEEL WATER SUPPLY CONDUIT.

CORROSIVE INFLUENCE OF SOILS AND WATER.—The portion of the steel conduit examined was subject to severe corrosive influences on account of the physical and chemical character of the soil. The conditions observed were reported to be fairly typical of the areas wherever the trouble had occurred in the southern half of the conduit. That the soil played an important role in the corrosion, is proved by the fact that the trouble only occurred to a serious extent in wet clay or water-logged soils, i. e., ground conditions in which excessive moisture was the normal state. As will be shown later, because of the remarkable power of dissociating the molecules of other substances, water readily becomes the medium by which the earth conducts electrolytically, and is, therefore, the arch enemy from which underground steel pipe should be shielded. The only possible solution of the corrosion problem lies in the prevention of the access of water to the surface of such structures.

Under all conditions, water is the essential agent of deterioration or decay in buried metallic structures; other influences, electric currents, atmospheric air, chlorides, organic and inorganic acids, promote or accelerate the process when acting with or through the medium of water, but would be inert in its absence. Owing to the mobility of its ions, water is not only the main vehicle for the processes of life, but also the principal medium of the changes that take place after death. The chemical and electro-chemical reactions that occur in the animal, vegetable and mineral kingdoms are hindered, or stop altogether in the absence of water. As found in nature, water is never pure, and the intensity of its corrosive nature can be gaged by the character and concentration of the gases and salts held in solution. The air contains innumerable solid particles, consisting of organic matter, common salt, sulphate of soda, lime salts and other electrolytes, including corrosive gases, all of which are brought down by rain. After reaching the earth, the composition of the water will be affected by the character of the surface soils and subsoils it flows over or sinks through. Waters flowing over rocky or clean beds of gravel and sand are obviously much purer and less corrosive than when contaminated by cultivated land, where there are deposits of animal or vegetable matter undergoing decay or putrefaction.

Touching the chemical nature of the soils in contact with corroded portions of the Rochester Steel Conduit, analysis revealed the presence of minute amounts of certain soluble salts (chlorides), which are among the most energetic and formidable rust formers of nature. These substances have the power of overcoming "passive" resistance catalytically, or by chemical induction, and thus render metallic surfaces "active," i. e., subject to corrosion, by giving the preliminary impulse needed to dissipate chemical equilibrium. Passive resistance belongs to a class of phenomena of which we have little definite knowledge. A characteristic of the passive state is that it prevents the mode of motion incident to chemical change. Incidentally, it might be said that if some means could be discovered of rendering metallic surfaces permanently passive, the corrosion problem would be solved. Frequent attempts to devise such a method have hitherto been unsuccessful.

Corrosion is primarily a solution process, oxidation being due to secondary reactions. Since water is the universal solvent of nature, it is the principal medium of the corrosive changes that take place in buried metallic structures, and the rate of deterioration will generally vary according to the porosity or imperviousness of the soil. Soils absorb water or allow it to percolate. Apart from porosity, the amount of percolation is governed rather by the time at which the rain falls, and the manner in which it is distributed, than the actual quantity. The density, looseness or open nature of the soil much affect absorption. Thus, loam, sandy and gravelly soils readily admit water, but on account of their incoherent quality offer slight resistance to its passage into the greater depths of the earth. The water of the soil does not entirely get beyond atmospheric influences, even at a depth of 10 ft.; thus sandy, porous and gravelly soils lose much of their water by evaporation, while clay soils absorb water like a sponge, and hold it tenaciously. From the accumulation of water in relatively impervious strata of this latter character, the soil becomes water-logged. Such clayey or marshy grounds are generally actively corrosive, and steel pipes buried in soils of this nature are in a perpetual state of siege. Precisely these conditions were observed around the damaged sections of the uncovered steel conduit at Rochester. No coating has yet been found that would permanently withstand severely corrosive influences of this character. Under the circumstances described, it was shown that asphaltic pipe dips are mere expedients, which may delay, but do not prevent corrosion.

In porous, gravelly soils, the corrosion processes are either inactive, or proceed very slowly, even in the absence of protective coatings. Moreover, the oxidation changes suffered by the usual coatings are greatly retarded.

No serious trouble has occurred in the portion of the steel conduit where the soil conditions are like those last described.

IRREGULARITIES OF STRUCTURE AND SEGREGATION.—Although defective coatings and soil conditions determine the extent of rust formation in underground steel water mains, the character of the corrosion is fixed by physical irregularities or segregation of impurities, in the metal. The fact that some of the plates of the Rochester steel conduit were damaged by pitting, and a greater number were not, where the influences were identical, proves conclusively that some inherent property in the metal was a factor in the trouble. Unless irregularities of structure or composition exist, there can be no difference of potential, and thus the corrosion would not be localized or concentrated at definite foci.

It is probable that surface irregularities in the pipe conduit were physical rather than chemical; influences apparently slight utterly change the structure and physical properties of steel, while not affecting the composition. For example, there are certain critical temperatures, around which important molecular changes occur in steel. If a specimen of mild steel containing 0.35% carbon, be heated for two hours at 675° C. and cooled slowly, and another piece of the same steel be heated two hours at 775° C. and cooled in air, and prepared sections of each are afterwards examined under a microscope, the two will present a very marked difference of crystal form. Such modifications of structure cause variations in the solution pressure in different portions of the same plate, and give rise to sufficient difference of potential to start localized corrosion processes in wet soil, or in the presence of other suitable media.

In general, iron which has been subjected to a strain or uneven treatment corrodes much more readily than that which has been treated uniformly. The strained part becomes electropositive to the unstrained. It is well known that mechanical stress, scratches, or what might be called wounds to steel, render the portion affected doubly susceptible to corrosion. Moreover, accidental breaks either in the surface of the metal or the scale have an important influence in locating corrosion centers.

With reference to local irregularities of structure, it is a physical impossibility, even with the most refined methods, to treat all steel surfaces, or the whole of any steel plate, alike. Besides blows, strains and other causes of local surface differences, the center will cool more slowly than the edges, and this cannot be prevented.

On account of the minute percentage of impurities contained in the low carbon steel of the Rochester conduit, it is not probable that segregation played any serious part in the trouble there. Since this inherent source of corrosion, however, is never entirely absent from steel, salient facts concerning it will be given.

Segregation is one of the inevitable defects of the present methods of manufacture. The steel on issuing from the furnace consists of iron, and carbon compounds of iron, associated in a heterogeneous liquid mass, with small quantities of manganese, silicon, phosphorus a sulphur. The metalloids in different combin s, i. e., the carbides, phosphides and sulph of iron and manganese, being lighter than mother metal, rise to the top in the molten te, while the purer iron sinks to the botton he lower part of the ingot will thus contain m less than the average of impurities, since wh r excess is in the top must be taken from bottom. Although this irregularity may be i rt counteracted by repeated heatings and gs, and a great amount of working, it can n be overcome entirely. Steel will not be ab ely uniform, and different rolled section ill give slightly different analytical results.

The summary of a study of segrega in steel shows that it is ever present, that t extent of the concentration bears a relation to proportion of impurities; that manganese d not apparently segregate to any extent, bu that certain portions of finished material wi contain a higher percentage of carbon, phos rus and sulphur than will be found in the test pieces cut from the edge of plates and bars. If a low carbon steel is low in phosphorus and sulphur (0.05%, or below), segregation is not liable to occur, and a degree of uniformity for practical purposes may be expected.

ELECTROLYSIS. — According to existing views, corrosion is an electrochemical process and can be readily explained under the modern theory of solutions. Owing to the differences of potential, the surface of the metal establishes a flow of current by means of an electrolyte. In order that rust may be formed, a metal must first go into solution and hydrogen be given off in the presence of oxygen, or certain oxidizing agents. This presumes electrolytic action, as every metallic ion that appears at a certain spot demands the disappearance of a hydrogen ion at another. There is no actual lower limit to the potential difference at which the process will not occur, provided the surface of the metal is not in the passive state.

Electrolysis is the decomposition of conductors of electricity by the passage of the current and occurs at the surface in contact with the liquid conductor. Both electrodes may be the same metal, and the electrolyte a compound of the same metal. The metal goes into solution continuously at the anode as long as the voltage is sufficient to remove the hydrogen at the cathode. In the electrolysis of iron or steel embedded in the earth, the ferrous ions liberated at the anodes undergo secondary chemical changes in the presence of alkaline salts or dissolved oxygen, resulting in hydrated ferric oxides, or the compounds found by analysis in rust pits. The chemical reactions by which secondary products are formed occur with a speed which is infinitely great in comparison with the other processes.

Electrolysis occurs as a natural process in buried iron and steel pipe where inadequately protected, provided the ground conditions afford media for solution and electrolytic conduction. A number of instances have established that in the presence of a minute amount of soluble salts in wet soils, normal electrochemical action may produce current enough to be very destructive in time. Wherever the action starts, it is continuous, unless the initial conditions are modified. Precisely these influences are found in the steel conduit at Rochester, and electrolysis from natural causes resulting in serious damage is the outcome. Along the surface of the pipe, there exist under the conditions what are called galvanic elements, i. e., chemical systems in which the transformation of energy associated with the changes of matter succeed in producing electromotive activity. It is now recognized that the chemical reactions which take place between the metal and the electrolyte furnish all the energy necessary for the production of the electric current. In the presence of the electrolytes of the wet soil, minute differences of structure or impurities in the plates form with the steel miniature voltaic cells. The chemi-electromotive force generated starts currents flowing around in short circuits, from the steel through the electrolyte, to the foreign particles, and back to the steel again. The impurities form with the

positive element minute voltaic couples, and thus direct the corrosive action of the electrolyte to the portion of the plate near them. Wherever the current leaves a plate to pass into wet soil, electrolytic corrosion must take place. A steel pipe is ordinarily not in uniform contact with the surrounding soil owing to the coating and other causes. The current leaves where the contact is good, or at points where the least resistance is offered to its passage. This is a reason why the corrosive action is concentrated in spots, and the phenomenon of pitting occurs. The rate of change in the corrosion or pitting process can be expressed as a mathematical quantity according to the law of Faraday: The quantity of electricity that suffices to deposit one electrochemical gram equivalent is $\frac{1}{1.035} \times 10^5 = 96{,}500$ coulombs (ampere seconds).

It was long believed that a voltage below 1½ volts could not produce corrosion, since it was below the dissociation voltage of water. This is a mistake, however, because when a current passes from iron through ground to iron and produces corrosion, the counter electromotive force is only a fraction of a volt. It has been experimentally proved that a small fraction of a volt, a mere directive force in the nature of electric pressure will produce enough current to cause electrolysis with the conditions generally present with underground pipes. Minute quantities of free carbonic acid or chlorides are nearly always present in the soil, and either of these substances render metallic surfaces active. The chemical processes previously described are capable of yielding ample current to start corrosion in wet soil, and this action of itself replenishes salt required for electrolytic conduction. The amount of corrosion depends not so much upon the strength of the current as the time during which it acts. The actual damage is very much dependent upon whether the exit of the current is concentrated in a small area or distributed over a large area. Experience, as at Rochester, shows that electrolytic corrosion ordinarily takes place in spots, producing pittings in the pipes, which indicates that the current leaves the pipe at these spots only; pipes are in this way much more quickly destroyed than if the corrosion took place uniformly over the entire surface.

Pitting and tuberculation are the forms in which corrosion is commonly manifested in iron and steel water mains. The phenomena of both are due to one principal cause—the solution and precipitation of the metal locally, as a result of electrochemical action. If the curent leaves from the outside of the pipe to pass into the soil, for reasons previously given, electrolytic action is manifested in the form of pits. But if the current passes from the interior of the pipe, tubercles covering pits usually develop. Owing to more uniform electrical conditions over the interior surface of pipes, the action is less concentrated, and thus serious damage from tuberculation rarely occurs.

The term "electrolysis," in connection with underground metallic structures, has hitherto generally been confined to the corrosion which could be traced directly to outside currents of electricity, commonly called earth currents, stray currents or returns from rails. There have been many instances near cities of destruction of underground water pipe by currents from these sources. In the study of the corrosion of the Rochester steel conduit, precisely similar results were observed where the effects of stray currents are completely excluded. The familiar soft spots that occur as the result of electric currents were found in the steel pipe, where the presence of return currents is out of the question. The chemistry of the corrosion process going on in the Rochester conduit is precisely the same as in ordinary electrolysis due to return currents from rails or industrial sources. The difference is that at Rochester we have electrolysis in which chemical action is the cause of the current, whereas in the presence of return currents, the chemical action is the effect or result of the stray current, from whatever source. To the former phenomenon of corrosion, in the absence of outside currents, the writer has given the name "auto-electrolysis."

THE NORTHERN HALF OF THE CONDUIT.—According to the reports of the engineer in charge, only a small portion of the northern half of the conduit has been affected by corrosion, and this for a distance of less than ⅔ of a mile, in low, wet ground, mainly through a cedar swamp. Fourteen rust leaks occurred here, between 1903 and 1907, which were repaired, and the pipe was recoated in the manner previously described through this small area.

The better conditions existing in the northern half of the conduit are, no doubt, chiefly due to the more favorable soil influences there. This portion of the pipe is generally laid through sandy loam, from which water easily drains away naturally, while much of the southern half of the pipe is laid in clay more or less saturated with water. It is probable, moreover, that the Sabin japan coating afforded a better protection than the asphalt pipe dips given the southern half of the pipe. For years after this process was applied, it was believed that an ideal method had been found of protecting steel water mains. While apparently more durable by several years than the asphalt pipe dips, the Sabin japan coating proved to some extent a disappointment at Rochester. Where the soil influences were really severe, as in the cedar swamp, the coating gave way, as evidenced by the number of rust leaks, and but for the pipe being promptly uncovered and recoated, disastrous consequences might have followed.

CONCLUSIONS.—(1) Electrolytic action occurs naturally to a greater or less extent in iron or steel structures embedded in the ground, unless protected from the access of water. Even in the best or most homogeneous steel there are contiguous areas of different electrical potential, and if an ionized solution (e. g., soil water) remains in contact with the metal, corrosion takes place in accordance with the laws of electrolysis.

(2) The corrosion of the Rochester steel conduit was caused by electrolysis, the current for which resulted from chemical processes between water solutions in the soil and the metal.

(3) The trouble was confined to areas in which excessive moisture was normally present, or where the soil was wet for considerable periods. The soil water in contact with the steel produces chemi-electromotive force from electrochemical action, and the electrolytic damage is proportional to the time during which the current acts. In the sandy or well-drained soils, excessive moisture is not in contact with the metal long or continuously enough for the feeble current to give rise to damage.

(4) The actual damage from electrolytic corrosion depends upon whether the exit of the current is concentrated in a small area or is distributed over a large area. If the current leaves the plates in spots (owing to breaks in the coating, or local irregularities in the steel) the pipes are much more quickly destroyed than if the corrosion takes place uniformly over the entire surface.

Electrolytic surveys which consist of voltmeter readings are not sufficient to determine the existence and extent of electrolytic corrosion. Direction and strength of current-flow in various parts of the system are required in addition to the voltage readings.

No general laws can be laid down as to the resistance of iron or steel against corrosion, as this depends upon composition, structure, accidental causes and the surrounding conditions of exposure. At Rochester it was found that serious damage by corrosion in the steel main ensues where three conditions meet: Ineffective protective coatings, irregularity of structure and composition of steel, and wet soils. Iron offers so little resistance to corrosion that there are almost no circumstances of service in which it can safely be placed without some means of guarding against deterioration. While the usual bitumen coatings no doubt delay corrosive action, the protection afforded, as shown at Rochester and elsewhere, is not durable in wet soils. For such severe conditions no permanently effective coating has been discovered.

Irregularity of structure and composition of steel, giving rise to surface differences of potential, cannot be entirely prevented. This fault, however, may be greatly lessened by care in manufacture, by cutting down impurities to an irreducible minimum, and by rigid inspection, rejecting all plates showing scars, scratches, or evidences of segregation.

The conclusion is thus reached that the most efficacious measures to be observed for prolonging the serviceable life of steel water mains lie in modifying the ground conditions wherever excessive moisture exists. This may be done by surrounding the pipe with sand and gravel, by avoiding the maximum water table, by drainage, and by avoiding, as far as possible, laying steel mains through wet areas.

OTHER STEEL CONDUITS.

It was deemed advisable to collect data concerning other steel conduits for comparison with the experience at Rochester. The opportunity was not afforded of observing precise conditions, but essential facts were secured through correspondence with engineers of eight different water supply systems, where steel mains had been for a number of years in service. Replies were received from the following cities and water companies: Portland, Ore., Atlantic City, N. J., Cambridge, Mass., New Bedford, Mass., Allegheny, Pa., Pittsburg, Pa., the East Jersey

A Corroded Section of the Portland, Ore., Steel Conduit.

(This 35-in. steel riveted pipe was laid in 1893 in clayey soil; water was found in the trench when the pipe was uncovered in 1906.)

Water Co., and Minneapolis, Minn. The information obtained related to the character of the steel used, the coating or method of protection, the character of the soil, the nature of the corrosion, if any, and the extent of deterioration. Only a brief synopsis of the reports received will be given.

THE PORTLAND STEEL CONDUIT.—A nearly parallel case of corrosion exists at Portland, Ore., to that at Rochester, although the damage sustained is not so great. The writer must acknowledge indebtedness to D. D. Clark, Engineer of the Portland Water Board, for a very complete and interesting account of the trouble there.

The Portland steel water supply conduit was laid in 1893-4 and is about 24 miles long. The average diameter of the pipe, the thickness of the plates, the specifications for the steel, and the asphalt coating, all agree very closely with the same features of the Rochester conduit. The pipe trench averages 6½ ft. deep, and the soil is mostly of a clayey character, with occasional wet areas. Damage from corrosion became manifest 10 years after the pipe was laid, and leaks in the plates began to appear. The pipe was uncovered at these points, and underneath the rusty looking clay which adhered to the top of the coating numerous pits were discovered. Analysis of the soil failed to show the presence of corrosive constituent. Nothing is said of outside sources of electricity; electrolysis from stray currents apparently being out of the question. The points where the principal leaks have occurred are from 12 to 14 miles from Portland where the soil in which the pipe is buried is a

yellowish, sandy clay. The surface of the ground here has a slight slope transversely to the line of the pipe, and in consequence water accumulates in the trench to some extent. The water in conjunction with the clay is supposed to be harmful, since it is noticed that at other points where the same quality of clay exists, but the water is not so abundant, the corrosion is much less apparent. Mr. Clark calls attention with emphasis to the condition of the pipe where buried in sand; no pitting of plates observed, and but few spots of rust.

After the occurrence of a number of leaks in 1895, the conduit was uncovered at twenty different points, aggregating a length of 590 ft. Only the upper half of the pipe was examined, but pittings large and small, found and counted, numbered 1,088. Many of these pits were ¼-in. in diameter and some were so near the point of breaking through that they were plugged before refilling the trench. In some places the clay was quite wet, and water accumulated in the trenches when opened. The pipe was found to be in the worst condition where the clay was wettest.

At a point where the pipe was laid in gravelly soil, which allowed surface moisture to readily drain away, no pits and but few signs of rust were found, and the coating was in fair condition. The same was found to be true in a river bottom, where the trench was entirely in sand; here the pipe was in excellent condition, with no pitting in the plates and only a few rust spots around the rivet heads.

All pipe sections examined in sandy or gravelly soils appeared to be in a fair state of preservation, and afforded a striking contrast to the damaged state of the pipe wherever uncovered in wet clay soils.

After a careful investigation of the corrosion of the steel conduit, Mr. Clark concluded a report to the Portland Water Board with the following statement:

> The indications are that the trouble is due to the nature of the steel of which the plates are made, and the readiness with which it is corroded by the action of soils and water; and hence the insufficiency of the asphalt coating is largely a contributory cause.

The corrosion of the Portland conduit is very similar to that at Rochester, and is probably due to the same causes. It is but another case of auto-electrolysis. The electrical conditions are apparently more uniform in the Portland conduit, and the points of exit for the feeble current generated along the surface of the pipe more numerous, which accounts for the great number of pits. The intense local action being thus less concentrated, the actual damage has progressed more slowly.

ATLANTIC CITY.—The earth and water of salt marshes near the sea or adjacent to estuaries are actively corrosive to buried metallic structures. A typical example is found in the 30-in. steel water main of Atlantic City, N. J. This conduit, about five miles in length, was coated with mineral rubber, and laid through a salt marsh in 1901. The engineer and superintendent, Mr. Van Gilder, gives few details, but writes that the pipe is rapidly deteriorating.

A verbal statement from an officer of the New York and New Jersey Water Co. represented similar conditions of steel pipe corrosion where one of their mains was laid through a salt marsh. It has been observed that clay soils impregnated with salt or brackish water are much more corrosive than sandy soils similarly situated.

CAMBRIDGE, MASS.—The corrosion of the 40-in. pumping and distributing main of Cambridge by electrolysis from stray currents has been carefully studied, and the results are too well known for repetition. The specifications for the steel were the same as at Rochester, and Portland, and the Sabin process was used for protection. It is worthy of remark that the greatest damage was wrought where the soil was a moist sandy clay. It is therefore probable that the function of outside currents was merely to hasten greatly a process that would have occurred naturally in time.

NEW BEDFORD, MASS.—The 48-in. steel force main of New Bedford, consisting of soft steel coated with the best quality of asphaltum, is eight miles long, and has been in service about ten years. The soil in which the pipe is laid is generally of drift formation, and is chiefly composed of gravel, sand and boulders. Two miles of peaty swamp was passed through, into which gravel was hauled to cover the pipe. No trouble from corrosion. Peat is said to be non-corrosive by some authorities.

PITTSBURG.—The 42-in. steel main laid for the water supply of Pittsburg in 1902, consists of open hearth steel plates. Mineral rubber coating was used for protection. The soil through which the pipe passes varies from shale and clay to sand and gravel formation. Trouble from corrosion has only occurred in one locality, near the power-house of a street railway, where one leak and a number of deep pits have developed. The action is attributed to outside currents, and in order to arrest it the pipe line system has been connected directly with the bus bar generator in the power-house, making the pipe line negative to the railway tracks. It is of interest to note that the bitumen coating failed to prevent electrolysis, whatever may have been the source of current.

ALLEGHENY, PA.—The steel for the Allegheny water main was made by the open hearth process, the specifications being very similar to those for the Rochester and Portland conduits. The pipe was coated by the Sabin method, and passes through a sandy loam and shale rock soil. No evidence has appeared of exterior corrosion; the interior of the pipe has not been examined.

MINNEAPOLIS, MINN.—The water main laid in 1898 is of mild steel, and was coated with "mineral rubber." The pipe is embedded in hard, yellow clay. The soil is damp in places, but nowhere could it be called wet. No water developed in the trenches. The pipe has been examined in a number of places and found in good condition.

EAST JERSEY WATER CO.—The steel main of this company has been in service since the early '90's, and is often cited as having given no trouble from corrosion. Bitumen coatings were used for its protection. General features of the soil as described by an engineer formerly connected with the company would suggest conditions which are not generally corrosive. The soils have weathered from the glacial drift overlying that region, and range in character from thirsty, gravelly uplands, to sandy, alluvial loams in the lowlands. Some tuberculation has occurred on the interior of the pipe, but wherever the exterior has been exposed, it was found in good condition.

THE DURABILITY OF STEEL, WROUGHT IRON AND CAST IRON.

This subject can only be discussed very briefly. There is a wide divergence of opinion among metallurgists on the corrodibility of the various forms of iron. Experience at Rochester, Portland and elsewhere seems to show that cast iron resists corrosion better than ony other form of iron, and wrought iron is less easily corroded, than mild steel. As between steel and wrought iron, some metallurgists claim that the difference is slight, but their reported experiments have not been carried far enough to base a final opinion. The corrosive influences of nature can never be precisely imitated, and, moreover, the time during which laboratory experiments extend is relatively so short that they are of little value compared to actual experience. Besides, practical experience on such subjects is always more reliable than mere laboratory experiment.

Several instances are related of steel bridges in New England and the West, erected during the last quarter of a century, that have already become unsafe from corrosion, while similar neighboring wrought iron structures twenty years longer in use are standing apparently unimpaired. There is a prevalent and widespread conviction among engineers that steel corrodes much more rapidly than wrought iron, and while the opinion may not rest on experimental evidence, the reasons for it are sound. Wrought iron differs from low carbon steel, in that the latter is free from slag, and the former contains only a trifling amount of manganese. Wrought iron consists essentially of a metallic matrix identical with low carbon steel, in which is mechanically mixed a small quantity of slag is far from unimportant, and [illegible] counts for the resistance wrought [illegible] corrosion. It is the characteristic [illegible] wrought iron, which usually contains [illegible] to 2% by weight, and often as much [illegible] volume. In composition, it is a [illegible] silicate, and is present simply becau[illegible] riety of iron is made by welding toge[illegible] temperature pasty granules of iron [illegible] such slag, without subsequently mel[illegible] sultant mass, or in any other way [illegible] envelopes of slag imprisoned a cha[illegible] cape completely. Wrought iron is n[illegible] thing by any means. Its character d[illegible] chemical composition, and this in tur[illegible] composition of the pig iron from [illegible] made, and the care and skill with [illegible] operation of manufacture has been [illegible] The five elements in pig iron affect [illegible] silicon, carbon, manganese, phosphor[illegible] phur. Experience has shown that [illegible] nearly steel approaches a pure iron, [illegible] it resists corrosion. The properties [illegible] iron are the nearest approach to thos[illegible] iron of any commercial material, not[illegible] ing its slag. This is because the slag is mechanically mingled, and does not interfere with the chemical or physical properties of the product.

On account of the honeycomb structure of wrought iron, and the fact that many of the globules of iron are encased in thin siliceous shells, which are non-conductors, the electrical resistance offered is sufficient to prevent damage from feeble currents generated along the surface of a pipe. The slag content affords the same kind of protection to cast iron. In limiting electrolytic action, the units of iron enclosed in silicious shells behave like water-tight compartments in a ship; owing to the small surface exposed, the current arising naturally is not of sufficient intensity to produce destructive effects. neither cast iron nor wrought iron resist outside currents of high voltage, although damage by electrolysis proceeds more slowly than in steel. A reason why steel yields more quickly to electrolytic action is that the combined carbon forms with the iron a complex ion, and is carried with it in the direction of the current, while the dissolved carbon and graphite in cast iron are not carried with the current, but remain as a muddy deposit at the anode, arresting the action.

An important advantage of wrought iron is its rough surface to which paint or other protective coatings will adhere more firmly than to the comparatively smooth surface of steel. Other qualities of wrought iron which tend to make it less corrodible are the absence of blow holes, and the comparative absence of manganese, which is now believed to be an important source of electrolytic activity in steel.

The serviceable life of cast iron, wrought iron and steel structures cannot be determined, although by deduction it may be approximately estimated. It would be useless and misleading to attempt to establish any rule, the circumstances and conditions being so dissimilar. From England and France data have been obtained concerning the durability of cast iron and wrought iron as materials of engineering construction, and this may afford means of forming a fair estimate of the endurance of steel. The first cast iron bridges were built in England about 125 years ago. Wrought iron bridges were first constructed about 60 years later. Thus we have evidence of cast iron structures that are said to be not deteriorated from visible corrosion after more than a century of service, and wrought iron plate bridges after 60 years.

Examples of great durability of cast iron water pipe have recently been published. Mr. C. Cavallier, director of the foundries at Pont-a-Mouson, France, gives some interesting records of long service of cast iron water pipes. Recently the first pumping station for supplying Paris with water was discontinued. The intake pipe extending out into the river Seine, being of no further use, was taken up. It was laid in 1802, and consisted of flanged cast iron pipes. After an immersion lasting over a century, these pipes were in such good condition that they

mi... have been relaid, but being an obsolete ty... were broken up and remelted. After re- m... the scale from the exterior, the words "... at an 10" could be read.

... Cavallier also mentions a number of an- ci... cast iron pipe lines which are still in use. The ...nduits which supply the water to the gr... fountains at Versailles date from the same pe... as the park itself. Five pipes, 20 ins. in di... er and 1,000 ft. long, were laid in 1685, or ... years ago. Several more pipes of various siz... having in all a length of about five miles, we... laid between 1668 and 1688. All the lines at ...sailles are made of pipe one meter in len... with bolted flanges. These pipes still serv... their purpose satisfactorily, and the few rep... which have been required have generally been necessitated by the condition of the flange bolts.

In Clermont-Ferrand there is a line of cast iron water pipe that was laid in 1748, or 160 years ago. These pipes are 0.5 to 0.8-in. thick, according to the pressure in the different parts of the line. The system is said to be still in operation under considerable pressure.

Other instances were given of cast iron pipe in service more than a century. Whatever method may have been used to protect these old French pipe lines had long lost its efficiency. The evidence here presented would indicate with proper precautions no practical limit can be given to the endurance of cast iron pipe.

The use of wrought iron for large steel water mains is of comparatively recent origin, beginning since the middle of the last century. Pipes laid during this period have given satisfactory service, with no serious trouble from corrosion, except from occasional cases of electrolysis due to outside currents. The durability of wrought iron will be better appreciated when the thinness of the plates is considered.

The application of steel to large water mains is of such recent origin that it may be considered to have scarcely passed the experimental stage, having begun only about 20 years ago. From careful study of information concerning ten steel water mains, subjected to dissimilar influences in various parts of the United States, the conclusion is reached that except where soil influences are severe the serviceable life of these structures will endure throughout the periods for which they are intended. It was previously recommended to modify ground conditions where severe. If this should improve impracticable, it would then be wise to substitute cast iron or wrought iron pipe in all wet areas.

SEWAGE PUMPING STATION AND SUBMERGED FORCE MAIN, SALEM, MASSACHUSETTS.

By WILLIAM F. BATES.*

The most interesting engineering features of the tidal water disposal system for the sewage from the city of Salem and town of Peabody, work on which was commenced in the fall of 1903 and finished in the spring of 1907, are the pumping station and force main (see Fig. 1).

In the designing of the pumping plant, one of the controlling features was that while the estimated amount of sewage to be pumped would not exceed 6,000,000 gals. per 24 hours, for some years, it was thought necessary to have a plant of sufficient size to maintain a velocity of 6 ft. per sec. in the outfall pipe, so as to thoroughly scour the pipe where it dips under the channel. As this high velocity would only have to be maintained for a period of from 1 to 2 hours, out of 24, no special provision for storage of the sewage was made, as the necessary amount for flushing could be stored in the main trunk sewer without causing any damage or nuisance.

Under the conditions, it was decided that the best plan would be to design and construct a plant of the full capacity of 19,000,000 gals., necessary to maintain the desired velocity, divided into units of such capacity as would allow for practically continuous pumping.

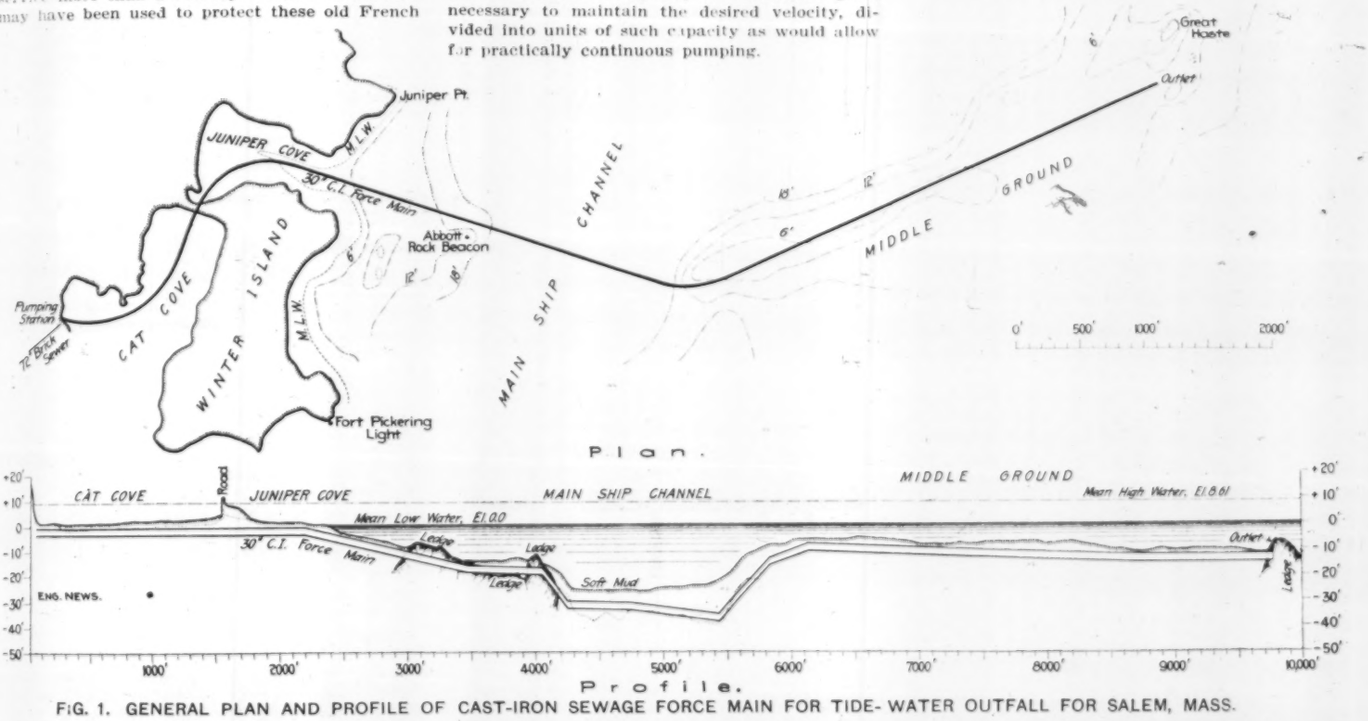


FIG. 1. GENERAL PLAN AND PROFILE OF CAST-IRON SEWAGE FORCE MAIN FOR TIDE-WATER OUTFALL FOR SALEM, MASS.

This called for a plant of four units (including one reserve unit) of 6,333,333 gals. each Three methods of operation were considered: steam, gas engine, and electrical power, and preliminary proposals were received and estimates of the cost of each method both for construction (including building and plant) and for operation were made and considered. The requirements were the same in each case; namely, a plant capable of 6,333,333 gals. against a maximum head of 18 ft., 12,666,666 gals. against a maximum head of 35 ft. and 19,000,000 gals. against a maximum head of 60 ft. The estimates for construction showed a great saving by using electrical power, both in cost and in ground space. The expense for a steam plant was about three times and the space five times that of an electrical plant; and for a gas engine installation the expense was twice and space three times that of electrical. In estimating the cost of operation, coal was figured at $4 per ton; gas at 75 cts. per 1,000 cu. ft., and electrical power at 1¼ cts. per HP. hr., on the basis of a 24-hour run, one hour to be at the rate of 19,000,000 gals. and 23 hours at the rate of 6,333,000 gals. per 24 hours, which it was considered would be the probable average rate for some time.

These estimates showed that, with the low price of electrical power, the cost of operation was about 50% more for steam and 10% more for gas than for electricity. The principal item causing the extra expense of steam over electricity was the necessity of having so much reserve power which would be used only 1 out of 24 hours. The estimates for operation under the conditions that will probably exist for a number of years, as well as first cost and minimum of attendance and space, were so favorable to electricity that it was adopted and plans prepared for electric drive.

The pumping station, as built (Fig. 2), is a brick building, 42 × 50 ft. in plan, with an ell 19 × 35 ft., containing the screen room and also the boiler room for the heating apparatus. The total cost of the station, including the pump well, was about $15,500.

The plant, as installed, consists of four 14-in. Worthington horizontal volute centrifugal pumps, mounted on the same base and directly connected to General Electric induction motors of 125-HP., wound for alternating current, 60 cycles, three-phase, 2,080 volts, and running at 300, 450 and 600 r. p. m. and delivering 62, 95 and 125 HP., with a full load efficiency of 88%. Full line current is used on each of the main motors. Cast-iron impellers are used and the pumps are fitted with special seals, in which oil was to be used, but which were connected by small brass pipes, filled with water under pressure from the city mains, used as a seal. The suction pipes are 16 ins. and the discharge pipes 14 ins. in diameter, and in each of the discharge pipes is placed a 14-in. Chapman gate valve, operated by a General Electric ½-HP., 1,200- r. p. m., 110-volt induction motor, controlled by an automatic switch. These valves are also arranged so that they may be operated by hand.

The priming of the pumps is done by two Knowles 4 × 4-in. dry-air vacuum pumps of the duplex type, of 201 r. p. m., belted to a General Electric motor of 5½-HP., 900 r. p. m., wound for alternating current, 60 cycles, three phase, 110 volts, and of the induction type. Each motor is connected with two transformers. The priming system is so arranged that any one or any combination of the main pumps may be primed by the use of either or both of the priming pumps. One-inch pipes are run from the

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highest part of the pump chambers to the back of the switch board, at which point valves are placed controlling each line, and the pipes are then joined and connected to the bottom of an air-tight chamber. Suction pipes from the priming pumps are connected at the top of the same chamber, in which is placed a balanced port valve connected with a copper float which controls the valve. This arrangement was designed to prevent the drawing of sewage into the vacuum pumps. To each of the priming pipes between the valve and main pump there is connected a combined pressure and vacuum gage, with dials mounted on the wall near the board, and on the side of the air-tight chamber is placed a water gage. This arrangement has proved satisfactory, excepting for some little trouble from leaves, etc., getting into the chamber, which has been remedied by placing a screen box in the pipe from the main pumps.

The switch board has six panels: one incoming line panel, containing one indicating watt meter and main switch; four pump motor panels, each containing one indicating watt meter, one controller handle, one automatic oil switch with the automatic switch for valve motor mounted on the sub-base, and one priming pump and lighting panel. On the sub-base of the priming pump panel are placed the valves controlling the priming pipes. The compensators are placed on the wall within a few feet of the board, so the operator may easily control the plant with very few steps. Any pump may be primed and started in less than three minutes. The discharge pipes from the main pumps are connected with a four-branch special casting, which reduces the curves to a minimum, and all piping is exposed and easily examined. From the special castings a 4-in. pipe is run to connect with perforated pipes in the bottom of well so that the pressure from the main may be used to stir up the sludge.

The head to be pumped against varies 11 ft. with the tide and it was planned to do the scouring, as far as possible, at low tide. Where the main sewer enters the screen chamber is placed a 72-in. Coffin sluice gate, and about one-half mile above the station an overflow from the main trunk sewer into the harbor was built, so that the station may be entirely shut off, if necessary.

No official long-time tests have been made, but a few unofficial short runs, at about one-half tide, have been made, with the following results:

One pump, 450 r. p. m., delivered 4,000 gals. per min., with an indicated load of 24 KW.
Two pumps, 450 r. p. m., delivered 7,000 gals. per min., with an indicated load of 46 KW.
Three pumps, 450 r. p. m., delivered 8,500 gals. per min., with an indicated load of 70 KW.
Two pumps, 600 r. p. m., delivered 9,000 gals per min., with an indicated load of 90 KW.

For the month of February, 92,000,000 gals. were pumped, with a total expense of power for all purposes of 10,100 KW. hours. The low price of 1.67 cts. per KW. hour, given by the Salem Electric Light Co., which concern furnishes the power, was given with the stipulation that the maximum demand for power, for flushing the sewer, was to be made only at such times as there was a light load on the station, and no power was to be taken at the time of peak load, excepting what was absolutely necessary.

The total cost of the plant installed, including screens, screen hoists, etc., was approximately $20,000.

As the expense of pumping will be paid in part by the city of Salem and in part by the town of Peabody it was decided to have an accurate reading of the volume pumped, and for this purpose a 30 × 15-in. Venturi meter was placed on the force main, near the station. It was found that at times of minimum pumping and low tide that if the meter was placed on the level of the station it would be working under a partial vacuum. For this reason, the pipe was dropped just outside the building, and the meter and registering apparatus were placed in a well, which is reached from the station by a flight of stairs. While this well is within a few feet of the water and the floor is 4 ft. below low water, no trouble is experienced from the moisture.

The outfall, which is believed to be the longest of its kind in this part of the country, extends from the pumping station 9,950 lin. ft., all under water, to its point of discharge near Great Haste Island. It is constructed of 30-in. cast-iron water pipe, of an average weight of 3,600 lbs. per 12-ft. length, and the line, as adopted, called for a trench of a depth of from 6 to 8 ft. near the shore and beyond the channel, and a depth of 12 to 15 ft. where crossing the main ship channel. This channel is about 1,500 ft. in width at the point where the line crosses. The depth of the pipe below low water ranges from 4 to 35 ft. Preliminary borings were taken at 100-ft. intervals, and, where rock was encountered, every 50 ft. These borings showed about 900 ft. of the trench to be in rock, which had to be removed to a depth of 6 to 8 ft.

The plans, as adopted, called for the laying of the pipe in sections 84 ft. in length, made up of seven 12-ft. lengths of pipe, with ordinary lead

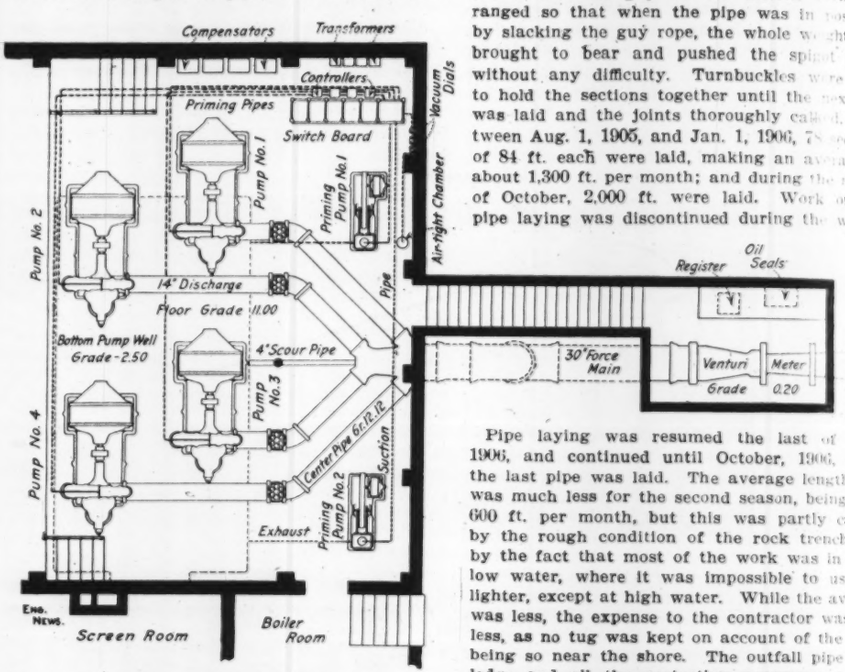


FIG. 2. PLAN OF SEWAGE PUMPING STATION FOR SALEM, MASS.

joints made above water, the ends of each section to be a slip joint. The slip joint was composed of a special spigot, made by turning down, in a lathe, an ordinary pipe to a slight taper. This spigot was inserted into a bell, the joint run full of lead and the pipes then disconnected, leaving the lead in the bell; and these pipes were connected under water and calked by a diver. The pipe was bought by the city at a cost of $34,300 delivered, including a charge of $840 for turning special spigots. Bids were called for and received March 31, 1905, for laying pipe, including all excavation, back-filling, etc., and ranged from $12.36 to $16 per lin. ft. These bids were on the basis of completing the work in one season. They were rejected as being too high, and new bids were called for, allowing two seasons to complete the work. The new bids ranged from $10.85 to $13.25 per lin. ft., and the contract awarded at the lowest bid.

Dredging was begun in June, 1905, but no pipe-laying was started until August. The plant used in laying the pipe consisted of a steam lighter and tug. The seven lengths were put together on the deck of the lighter and the joints run and calked. A 15-in. I-beam (Fig. 3) about 75 ft. in length, trussed laterally to prevent bending, was suspended from the block on the derrick boom by four strands of wire rope, spaced evenly on the beam; and to this beam the section of pipe was strapped with ½-in. wire ropes, two straps to each length, except the e[illegible] lengths, which were held by one strap. These [illegible]ps were connected at one end by shackles, wi[illegible] the pins so placed that they could be easily r[illegible]oved by the diver and the straps released aft[illegible] the pipe was in position. This I-beam was u[illegible] during the entire work and proved a very s[illegible] factory method of handling the sections, as [illegible] strain was brought to bear on the joints. T[illegible] I-beam, with a full section of 84 ft. of pipe, wei[illegible]d about 15 tons, and was easily handled by t[illegible] derrick. The pipe, after being lowered into [illegible] trench (which was from 12 to 18 ins. below g[illegible]e to allow the diver plenty of room for wor[illegible]g) was b'ocked up to the required grade an[illegible]eld in position by wedges. Guides were pla[illegible] on the bell end of the pipe in position; these g[illegible]es projected about 6 ins. beyond the end [illegible] were made so as to help guide the spigot [illegible]nto the joint, and at the same time protect [illegible]e lead from being jammed. The joining of t[illegible] special joint was directed by a diver. The lig[illegible]ter was placed and the guy on the derrick [illegible]om arranged so that when the pipe was in [illegible]osition, by slacking the guy rope, the whole w[illegible]ght was brought to bear and pushed the spi[illegible]t home without any difficulty. Turnbuckles [illegible]re used to hold the sections together until the [illegible]ext one was laid and the joints thoroughly cal[illegible]d. Between Aug. 1, 1905, and Jan. 1, 1906, 7[illegible] sections of 84 ft. each were laid, making an a[illegible]rage of about 1,300 ft. per month; and during the month of October, 2,000 ft. were laid. Work on the pipe laying was discontinued during the winter.

Pipe laying was resumed the last of May, 1906, and continued until October, 1906, when the last pipe was laid. The average length laid was much less for the second season, being only 600 ft. per month, but this was partly caused by the rough condition of the rock trench and by the fact that most of the work was in shallow water, where it was impossible to use the lighter, except at high water. While the average was less, the expense to the contractor was also less, as no tug was kept on account of the work being so near the shore. The outfall pipe is in ledge and all the protection necessary was to anchor it into the ledge with concrete. The dredging presented no difficulties, excepting where the rock was encountered. The rock proved to be very hard and full of seams and the whole rock trench had to be drilled and blasted at least three times, and some portions were gone over four and five times before a satisfactory trench was secured. In shallow water, the dredged material was piled along one side of the trench and the refilling was done with an orange-peel bucket dredge, while in the deeper water the refilling was done with small scows, care being taken, in dumping, not to disturb the pipe.

During the progress of the work, two breaks in the pipe line occurred, both of which were the result of peculiar accidents. The first break occurred on the work in shallow water, near the head of a cove. At this place, it was impossible to get the lighter into a position to lay the pipe in the long sections, and it was laid in sections of 24 ft. each. These sections were laid by a long boom on an orange peel dredge, and when four sections, or 96 ft., were laid and slip joints calked, filling was started at the back end of the section, and in some unknown manner the whole section was pulled out at the slip joint and pushed ahead bodily, 12 ft. At this point, the diver used a long pole, which was left standing at right angles to the end of the pipe laid, as a guide for lowering the next length. When the next section was lowered, the pole was found to be back one length, or 12 ft. from the end. The end of the pipe was tried for line and grade and

to be substantially correct, and the only explanation the diver could give was that he had made a mistake and placed the mark opposite the wrong joint. The work was continued and the break not discovered until the pipe line was tested. In repairing, it was necessary to take up 48 ft. and relay it, putting in an extra length and making a sleeve joint.

The second break occurred where the pipe crosses the main ship channel, the pipe at that point being 35 ft. below low water and in a trench 12 ft. in depth. No filling was done until the pipe laying was completed across the channel, but a short time before filling was commenced the whole line of pipe was inspected by a diver and reported to be in excellent condition, and filling was done from small scows so as to prevent any moving of the pipe. When the pipe was tested, a break was discovered in about the middle of the channel. The pipe was uncovered

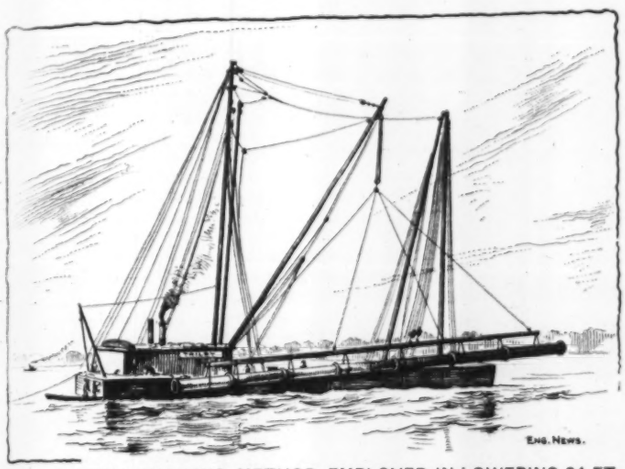


FIG. 3. SKETCH SHOWING METHOD EMPLOYED IN LOWERING 84-FT. SECTIONS OF SUBMERGED SEWAGE FORCE MAIN, SALEM, MASS.

and the divers reported that a section of two lengths, or 24 ft., was disconnected and lying diagonally across the trench. At one end of the disconnected section was a slip joint and at the other end was a cut spigot, with a wrought iron band, and this spigot had pulled out of the bell, leaving the band in the bell with the lead. The only explanation that could be given for this break was that in the short time that elapsed between when it was examined and the filling was done, it must have been fouled by the anchor of some large vessel and pulled apart. It could not have happened after the trench was filled, as the pipe was found at substantially the grade at which it was laid.

In order to repair this break it was necessary to uncover and take up one whole section, as one of the pipes in the middle of the section was found to be cracked nearly its whole length. The section was then made up and relaid and the joints made with a sleeve calked with cold lead by divers. The repairing of this break took about six weeks and cost the contractor about $9,000.

The total cost of the force main, exclusive of pipe, engineering and inspection, was about $110,000, including the pipe laying, which amounted to about $27,000.

In laying out the lines for the force main, the portion out to and across the channel was located by triangulation and stations were marked by fan ranges on the shore, but on that portion beyond the shore, other methods were necessary, as the nearest land was more than a mile distant. The water was from 6 to 18 ft. deep on this portion of the line, and 1½-in. wrought iron pipe, cut into 4-ft. lengths and joined by couplings, were driven on line at distances of 500 ft. Measurements were taken by small boats, using a 500-ft. tape, which was held at the surface of the water by means of small cork floats (such as are used by fishermen on seines) placed on the tape at intervals of 25 ft. Measurements were taken on calm days and no trouble was experienced in obtaining fairly accurate measurement. After the stations were established, pipes were driven for cross ranges to mark every 500-ft. station.

The chief engineer for the disposal system was Mr. Ernest W. Bowditch. The construction was carried on under the direction of the writer, as resident engineer. The general contractor for the force main was Mr. Patrick McGovern and the pipe laying was done by Mr. Alfred Sorenson, with George Deane as superintendent. The dredging was done by the Eastern Dredging Co. All the engineers and contractors named in this paragraph are located in Boston, Mass.

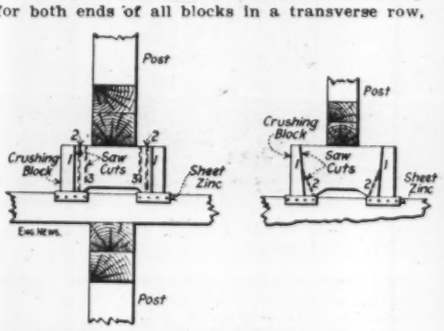
CRUSHING BLOCKS FOR LOWERING ARCH CENTERS.

An interesting device for striking centers of arch bridges was used in the erection of the masonry arches on the lines of the new Austrian mountain railways, which have been in process of construction for several years past. The device is a specially-formed crushing-piece of wood interposed between the lower and upper portions of the centering at each post. The block has sufficient bearing area to hold up its load during erection without sensible crushing, but it is so shaped that by sawing off the end portions of the block the bearing area may be successively reduced by half, two-thirds, and more if necessary, and thus caused to crush down and allow the centers to settle away from the arch.

The two sketches reproduced in the drawing herewith show two variations of such crushing blocks. The blocks are made of perfectly clear pieces of soft wood; where they bear on the sills the latter are protected by a plate of sheet zinc to distribute the pressure on the sills without affecting the crushing of the blocks. The lower side of the block has the center notched out, as shown, to a height sufficient to permit the centers to drop the desired amount.

The bearing area of the two feet of the block was proportioned to give a unit-compression of 440 lbs. per sq. in. under the full load of the completed structure, and the block was made deep enough to safely resist the shearing and bending stresses induced in it.

To strike centers, the two ends of each block were sawn through, vertically, at such a point as to take away just half the bearing area of the feet of the block. This was done simultaneously for both ends of all blocks in a transverse row,



Crushing Blocks for Lowering Arch Centers, as Used on Austrian Railway Work.

progressing from skewbacks to crown. The blocks having crushed down somewhat after this process, a second similar cut was made to further reduce the bearing area, in any desired proportion, beginning at the crown and progressing toward the skewbacks. It proved unnecessary in every case to make a third cut, the desired settling being secured after the second cut, but the process could evidently be carried farther. By passing the second cut as in sketch II, the maximum settling is secured on the second cut with greater certainty. Obviously the height of the notch in the block limits the drop of centers.

This method, described by Mr. J. Zuffer, in the "Zeitschrift des Oesterreichischen Ingenieur and Architekten Vereines," of March 13, 1908, was used in the erection of a number of large masonry arches on the line of the new connection between Trieste and Klagenfurt, Austria. It is said to have proved very successful.

THE WESTINGHOUSE DOUBLE-FLOW, IMPULSE-REACTION TURBINES AT THE BRUNOT ISLAND POWER STATION OF THE PITTSBURG RAILWAYS CO.*

The initial installation of a new and important type of machinery should always be of peculiar interest to all concerned in the progress of mechanical engineering. For this reason the following matter, relative to the recent extension of the Brunot Island Station of the Pittsburg Railways, employing the new Westinghouse double-flow turbine, should prove of interest. This station furnishes current for the greater part of the street railway system in Pittsburg and Allegheny, Pa., and in addition supplies current for a large part of the lighting of this district.

It is sufficient to state that the old engine plant consisted of five 1,500-KW., cross-compound, condensing engines, three of which were direct connected to three 550-volt, direct-current, railway generators and the others to two 6,600-volt, two-phase alternators running in parallel with the other plants of the system.

PLANT EXTENSIONS.

Owing to the extraordinary increase in the demand for power it was found necessary to increase the plant capacity considerably beyond original estimates. In the old building room had already been provided for three additional 1,500-KW., cross-compound, condensing engines but, as the necessary extension far exceeded these provisions, steam turbines were adopted with the result that it has been possible to install additional machinery of 18,000-KW. capacity instead of 4,500-KW. and there is still room for one more turbine. Each turbine has a short direct connection to a jet condenser. The supply and discharge pumps are mounted on the same shaft and are driven by a compound single-acting engine. The condensers and their pumps are located beneath the engine-room floor between the columns of the turbine foundations.

A steam-driven, dry-vacuum pump is provided for each turbine. The cooling water is pumped to the condensers from an intake tunnel extending the length of the power-house, at one side of the foundations, and the discharge from the condensers empties into a similar tunnel parallel to the intake. As the water level in the Ohio River during times of flood is occasionally as much as 28 ft. above the tunnels, special provision had to be made to guard against flooding the condensers. This has been accomplished by means of an adjustable gate in the intake-tunnel leading from the screen-house to a large central well in which the water level may be maintained at the desired height irrespective of the flood level.

FOUNDATIONS.—A noteworthy example of the slight foundations required for turbines is shown in the design adopted here. Each unit rests upon reinforced-concrete plates supported entirely by six reinforced-concrete columns thus giving ample space around the condenser which could have been placed entirely within the turbine foundations had this been necessary. It is interesting to note here that the concrete used in the foundation of a single one of the old 1,500-KW. cross-compound units would build the four foundations for this 18,000-KW. extension.

THE DOUBLE-FLOW TURBINES.

The preceding review of past and present conditions at this plant is intended merely as an introduction to the most novel features—the turbines. As this type is the most recent development of the Westinghouse Machine Co. and has

*Arranged from data and information furnished by Mr. J. R. Bibbins, M. Am. Soc. M. E., Mechanical Engineer, Westinghouse Machine Co., East Pittsburg, Pa.

been given little publicity the writer proposes to deal with these particular machines to considerable detail in what follows.

ADVANTAGES.—The double-flow design as embodied in these large machines, is essentially a modern development brought about entirely by considerations of improved mechanical construction. It is not by any means without precedent—in fact the original Parsons turbine constructed in 1880 was of the simple double-flow type. In modern hydraulic work the double-flow design is very largely employed to produce a rotor running in perfect axial equilibrium. In small machines, however, the advantages of the double-flow design are not as prominent as in the large units such as are employed in this extension. This is principally because of the mechanically satisfactory design of the single-direction type and partly because the economy of the two sets of turbine blades would not be as good as with a single set of double capacity. In very large sizes, however, each set of blades is of such capacity that conditions exist for the attainment of as high economy as obtain with a single set of double capacity.

The double-flow turbine may be regarded as the result of an insistent demand for turbine generating units of larger capacity at high speeds. For these large machines, the advantages of combining the impulse and reaction principles, together with the double-flow construction, are so important that for machines above 5,000-KW. capacity this design will become standard for all Westinghouse installations. This condition is largely brought about by the higher relative speeds permissible in large units by the use of the impulse section. The Parsons element, so used in connection with the impulse section, in machines of these capacities works to so much better advantage as to compensate for the somewhat lower inherent economy of the impulse element.

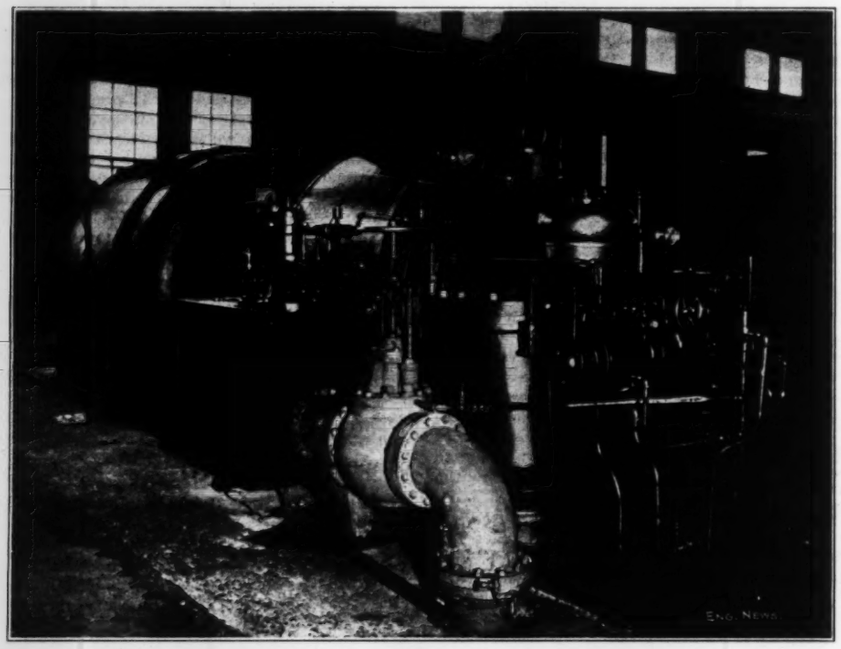


FIG. 1. TWO VIEWS OF A 5,000-KW. DOUBLE-FLOW STEAM TURBINE UNIT; BRUNOT ISLAND STATION OF THE PITTSBURG RAILWAYS CO.

The advantages of the double-flow construction will probably be most clearly understood by first considering the low pressure double-flow turbine shown in Fig. 2. Here is a turbine of the simplest possible construction, consisting entirely of two identical Parsons turbines, placed end to end, taking steam at the center and exhausting at both ends. It will be evident from an examination of Fig. 2 that, since the two elements are identical and the steam flows through them in opposite directions, the axial thrust of the steam on the blades due to the difference of pressure between the inlet and outlet of ea[illegible] will be exactly the same in both section[illegible] fore, perfect steam balance under all [illegible] of pressure, vacuum and load is obtain[illegible] the use of balance pistons. As such lo[illegible] turbines are designed to utilize all th[illegible] steam from a non-condensing, recipro[illegible] gine, it is possible to tie the engine a[illegible] together, electrically, making the use [illegible] gov-ernor on the low pressure turbine un[illegible] With the exception that the governor [illegible] be omitted from the low pressure t[illegible] mentioned, this arrangement of engine[illegible] turbine is theoretically almost identical [illegible] high-pressure, double-flow, impulse-rea[illegible] turbine. The addition of the simple, high[illegible] impulse element is shown in Fig. 3.

Before taking up the design of these [illegible] further it is of interest to note a few a[illegible] advantages of the new type. These are: (1) The cylinder casings are not subjected to [illegible] high pressure or high temperature, the m[illegible] pressure on them being about 75 lbs. per sq. in.; (2) the relative large volume per lb. of the steam admitted to the first Parsons section avoids the use of short blades otherwise necessary with large diameters; (3) the impulse element is suitable for high pressure and superheat and it works well into the mechanical design, reducing the shaft length, for the same output, by 50%; (4) only one balance piston is required and that a small one; (5) the exhaust connections through the bed plate are of small diameter on account of the divided flow.

STEAM PATHS.—Steam enters the turbine through a flanged opening in the lower half of the casing from which it is piped directly to nozzle blocks. After expanding in suitable nozzles, the steam impinges upon the impulse blades, enters the impulse wheel chamber and is distributed evenly around the casing so as to enter the intermediate Parsons section of the turbine, around the entire periphery of the rotor. The steam next divides along two separate paths, one half entering the left-hand section of low pressure Parsons blading, the other passing through the interior of the rotor shell which forms the connecting passage to the remaining low pressure section of Parsons blading at the right-hand end of the turbine. The steam discharging from the last rows of low pressure blading passes into the exhaust connections and to the condenser in the usual manner.

THRUST BALANCE.—As the same pressure exists on both sides of the impulse wheel disk, this is not subjected to any end thrust and requires no balancing. The difference of pressure between the inlet and outlet of the Parsons intermediate section is accurately balanced by a dummy piston, of moderate dimensions, located between the impulse wheel and the right-hand low-pressure section. And since the thrusts in the low pressure sections are in opposite directions and therefore balanced, the entire turbine runs in perfect equilibrium under all conditions of vacuum, pressure and load. It is, of course, necessary to provide means for accurately fixing the axial position of the rotor, and for this purpose, an adjustment bearing on the right-hand of the shaft, is, as usual, fitted. It consists of a number of collars turned in the shaft, into which fit corresponding brass rings fixed in the adjustment blocks. The upper and lower halves of the adjustment bearing may be moved by means of micrometer screws, as shown, thus permitting the axial position of the rotor to be accurately known at all times.

CYLINDER CASINGS.—All double-flow cylinders are made in two parts, the upper and lower halves each being a one-piece casting. The design is symmetrical throughout, devoid of longitudinal flanges except those at the center required for bolting the two parts together. The castings are first rough-bored, after the flanges have been planed and drilled, and are then "seasoned" with high-pressure steam for a number of hours to remove any local casting strains in the metal. They are then given the finishing cut, assembled, and with boring bar running in the bearing housing so as to insure a truly concentric bore. Manholes are provided at each end

of the cylinder to permit access for interior examination, and relief valves are fitted in each of the manhole covers to prevent the pressure in the exhaust passages rising to a dangerous point in case of failure of the condensing apparatus and sticking of the atmospheric relief valve.

EXHAUST CONNECTIONS.—A Y-connection, fitted with two corrugated copper expansion joints located below the base of the turbine, connects the separate exhausts to the main exhaust nozzle. This is shown by the longitudinal elevation of the 5,000-KW. unit in Fig. 5. By means of these expansion joints, the desired freedom of movement of the turbine casing, due to expansion and contraction, is provided for. It will also be noticed that an atmospheric exhaust nozzle opens out of the side of the exhaust "Y" to permit non-condensing operation.

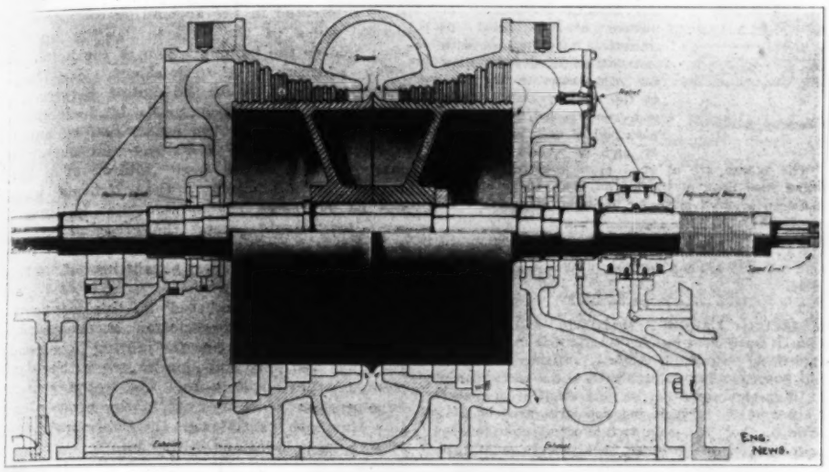


FIG. 2. A SIMPLIFIED DOUBLE-FLOW PARSONS TURBINE.

ROTOR.—The rotating element of the turbine is built up of five cast steel parts, in addition to the shaft. As may be seen from Fig. 3 these are the three Parsons blading supports, the impulse section and a dished plate. Of all these only the two final Parsons sections and the dished plate are directly carried by the shaft and then comparatively close to the bearings. This design allows a lighter shaft than would be required for distributed loading and practically eliminates deflection. This built up part of the rotor is locked to the shaft only at the right-hand support, the opposite end being fitted with a bronze bushing surrounding the shaft, permitting the rotor body to move axially without appreciable resistance under any differential expansion of shaft and rotor body.

The impulse section consists of a flanged, cast-steel disk forced on to the body carrying the intermediate Parsons blading. The flange of this disk is grooved at the base and forms the dummy piston for balancing the thrust of the intermediate Parsons section. Detail of the arrangement of nozzle and blades is shown in Fig. 4. It is seen that the nozzle block is a casting quite separate from the turbine cylinder casing. As it receives steam from the governor valve this restricts the high pressure and high temperature to a comparatively small casting which is free to expand and contract with changes of temperature.

As the steam is not expanded in the impulse element to less than half of the initial pressure, divergent nozzles are unnecessary and simple straight-sided nozzles are used. The entire nozzle block may be removed in one piece, and the construction is such that the nozzle walls may be readily renewed if necessary, at a very nominal cost independently of the block. As practically no difference of pressure exists on the two sides of the element, the area through the bucket increases to provide for the decreasing steam velocity in each rotating wheel. As in all high-pressure impulse turbines, the nozzle blocks cover but a small portion of the periphery of the impulse wheel, so that ample space is left around the remaining portion of the wheel to permit the free circulation of steam in all parts of the impulse wheel chamber before entering the Parsons element.

The construction of the Parsons elements, except for the divided flow of steam, is identical with the familiar single-flow construction and consists of a series of rows of moving and stationary blades which increase in height to allow for the increased volume of steam. It will be recalled that the blades are inserted in grooves cut in the spindle and cylinder body, and are securely held in place by calking the soft distance pieces inserted in the grooves between the blades. It will be noted that the diameters of the low-pressure section are chosen so as to permit the same size blades being used in both intermediate and low-pressure sections thus simplifying the blading considerably. As there are a number of improvements in the Westinghouse Parsons blade construction used on both the single-flow and double-flow turbines that have not been previously published, they may well be included here.

Blades.—No one metal has all the physical characteristics desirable in a blading material. But recently a special compound blade has been developed, which is exclusively used in Westinghouse turbines. This material, known as "Monnot,"* or duplex metal, consists of a steel core covered with a copper sheathing actually welded to the steel in such a perfect manner that the blades may be drawn cold from the original ingot into the required finished section without in any way affecting the bond between the copper and steel. The expected advantages of this blade are important as experiments have shown that pure copper offers the maximum resistance to corrosion from bad feed-water carried over in the steam during priming. At the same time the stiffness and strength of the steel core is maintained.

*"Monnot" copper-clad steel was described by an illustrated article in Engineering News of Nov. 14, 1907.

Packing Glands.—A water-sealed gland is fitted on each end of the turbine shaft where it passes through the exhaust casings. This packing consists of a small centrifugal pump propeller running in an enclosed chamber to which water is supplied under a head of about 10 ft. which is slightly in excess of the head due to the centrifugal force acting on the water in the impeller blades. At starting, any external leakage water is caught in circular troughs and drained away. The action of this gland is to always maintain a solid mass of water around the periphery of the impeller which effectually prevents the entrance of air to the condenser or the escape of steam to atmosphere when running non-condensing.

Governing.—Essentially the same system of governing is used in the double-flow as has become familiar in the single-flow design; that is, the "puff" or "gust" system comprising a constant number of admissions per minute with a variable duration of admission according to the load. This refinement of the purely throttling method, is distinctly different from the principle of governing by adding nozzle after nozzle, all at maximum pressure, as the load increases. Both the "puff" method and that of individual nozzle control may properly be regarded as purely mechanical methods of securing a constant-speed prime mover—neither possessing any important thermodynamic significance. In any multi-stage turbine, with individual nozzle control, it is difficult to maintain an equal distribution of work between the several stages without a means of governing the nozzles in each individual stage at the same time as the high-pressure stage. On the other hand, experiment has proven that, with the throttling method of governing, stage-pressure control in the multi-stage turbine is entirely unnecessary and that where the expansion in each stage is but a small part of the total expansion range, the initial and terminal pressures of each stage rise and fall together, resulting in a fairly constant pressure ratio at each successive expansion. That indicates that for small ranges and with throttle governing, the nozzle and blade areas are very nearly correct through a wide range of load and pressure distribution. For this reason, the impulse section of the Westinghouse turbine expanding, say only one-fifth of the total range, is properly proportioned for a wide range in load and may be governed without resorting to intermediate nozzle control and without any sacrifice of economy at fractional loads. The type of governor controlling the double-flow turbine is of the sensitive fly-ball type differing only in minor details from the standard governor for single-flow machines. Its most important principle is that of keeping all parts constantly in motion so as to avoid "friction of rest" and to prevent sluggish action which would otherwise ensue after running a considerable period at constant load. A small relay steam piston does the

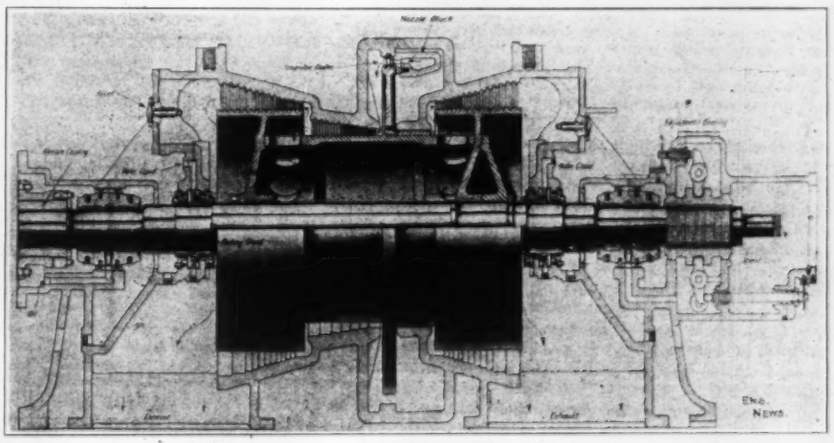


FIG. 3. A DOUBLE-FLOW REACTION TURBINE WITH A CENTRAL IMPULSE SECTION.

actual work of moving the turbine valves, thus relieving the governor of practically all work except moving a small pilot valve. For convenience, in synchronizing and distribution of alternating current load, the governor is fitted with a small motor and weight by which the governor spring tension may be controlled from a distance, usually from the switchboard.

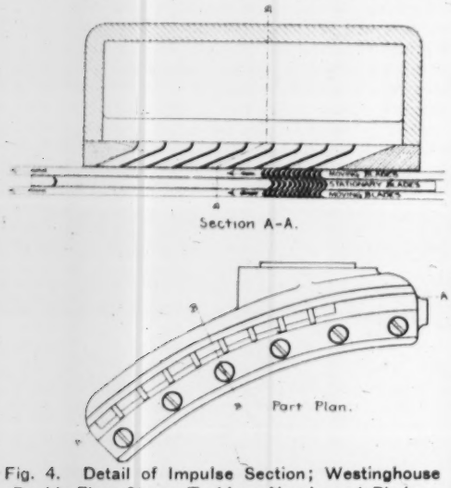


Fig. 4. Detail of Impulse Section; Westinghouse Double-Flow Steam Turbine; Nozzle and Blades.

A 120-TON ELECTRIC TRAVELING CRANE at the Southern Pacific Ry. shops at Bakersfield, Cal., is believed by the builders (the Whiting Foundry Equipment, of Harvey, Ill.) to be the largest crane of its kind in this country that is operated by alternating current. Its motors use three-phase, 60-cycle, 440-volt current. There are two 60-ton trolleys with 60-HP. motors, and each trolley has a 10-ton auxiliary hoist. The span is 57 ft. 4½ ins., and the height of lift is 22 ft. 6 ins. The bridge girders are of box section, with ⅝-in. web plates and four flange angles 5 × 6 ins. carrying top and bottom cover plates. The bottom chords are curved. Transverse diaphragm plates between inside stiffener angles transmit the load from the rail on the top chord plate to the web plates. These diaphragms are closely spaced in order to prevent any deflection of the chord plate and thus relieve the rivets of any bending stresses. The girders are connected by transverse steel frames with sufficient flexibility to allow for inequalities in the level of the runway rails. There is a two-wheeled truck under each end of each bridge girder, and the wheels have steel tires. The blocks are of steel plate construction, and the forged steel hook of the 60-ton block turns on steel balls between grooved plates of hardened steel.

THE NATIONAL RIVERS AND HARBORS CONGRESS will hold its next annual meeting in Washington, D. C., Dec. 9-11.

THE SECOND LARGEST MASONRY ARCH in the world has recently been completed on a new railway from Klagenfurth to Trieste, in Austria, crossing the Isonzo River at Salcano. The Salcano arch is the main span of a 721.8 ft. bridge consisting of nine small arches, averaging about 40 ft. in span and one large arch of 278.9 ft. and 78 ft. rise. The main arch is of cut stone founded on reinforced-concrete footings backing into solid rock. It is 6.6 ft. thick at the crown and 11.5 ft. at the spring. The 17-ft. roadway, for a single-track railway, is carried to the arch ring by a spandrel arch construction. As we have frequently noted before the largest masonry arch in the world at Plauen, Germany, has a span of 295 ft. and the hitherto second largest at Luxembourg, a span of 277.6 ft. This latter arch span length, however, is measured from the base of the arch ring where it is some distance below the surface of the ground. The actual apparent span of the Luxembourg arch is therefore some 20 ft. shorter than the real 278 ft.

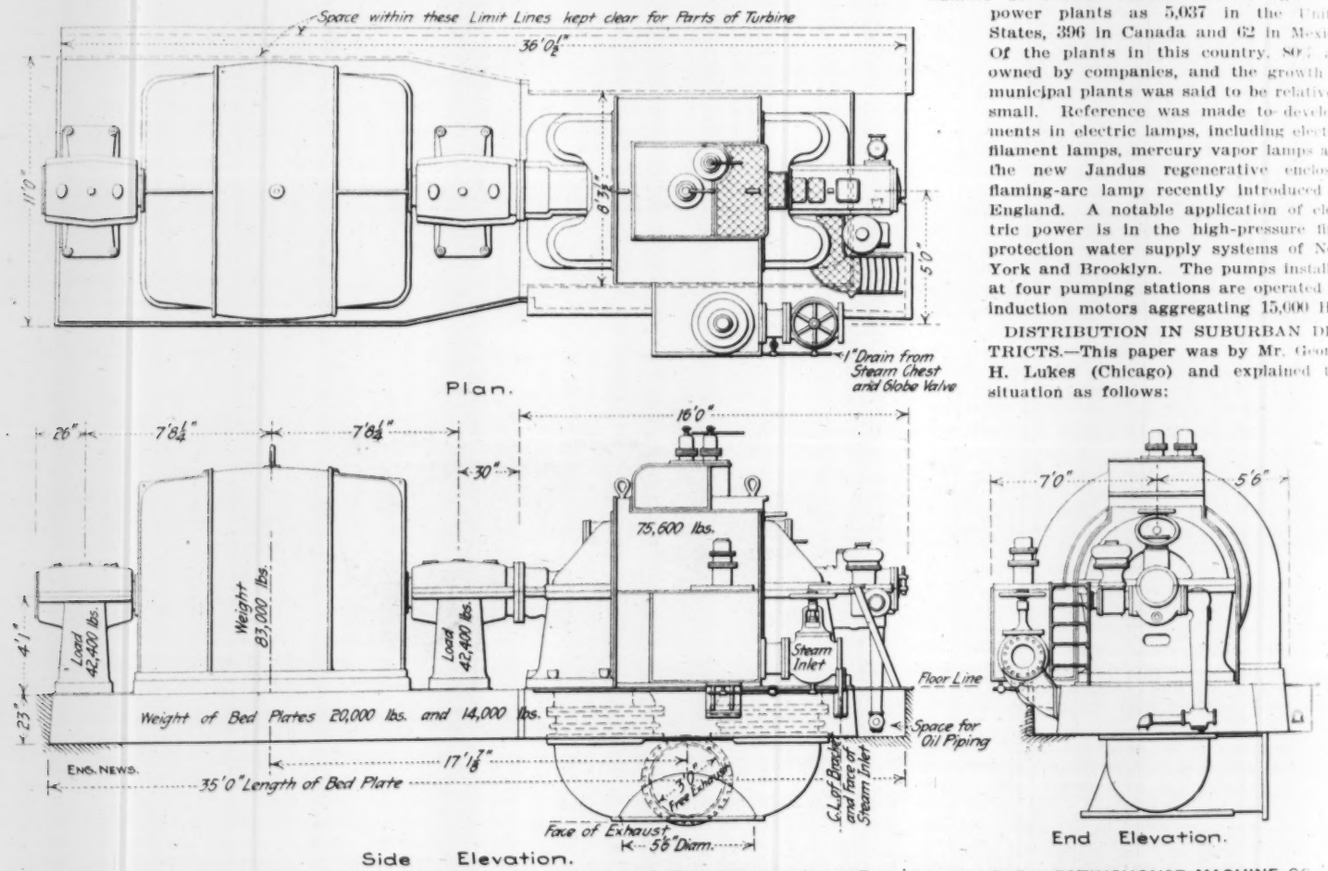


FIG. 5. PLAN AND ELEVATIONS OF A 5,000-KW., DOUBLE-FLOW, STEAM-TURBINE UNIT; MADE BY THE WESTINGHOUSE MACHINE CO., EAST PITTSBURG, PA., FOR THE PITTSBURG RAILWAYS CO.
175 Lbs. Boiler Pressure; 1,200 r. p. m. Condensing; Revolving Field, Three-Phase Generator; 11,000 Volts, 60 Cycles.

ANNUAL CONVENTION OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION.

The 31st annual convention was held in Chicago May 19 to 22, with an attendance of nearly 1,800 registered members and guests. The association has 1,327 members. The first session was called to order about 10.45 a. m. on Tuesday, May 19, in a hall of the Auditorium Hotel, in which the headquarters were established. During some of the sessions, branch meetings for those interested in the accounting and the commercial sides of the electric lighting business were held in the banquet room of the hotel.

The address of the President, Mr. Wiley Farrand, President of the Public Service Corporation of Essex County, N. J., dealt chiefly with the relation of the association to matters of public policy. He remarked that during the past year there had been failures of a large number of municipally owned lighting plants, and he expressed the opinion that in time the same fate would attend the great majority of such plants. Those remaining must have exceptional local facilities permitting of reduced operating cost.

It must be remembered in this connection, however, that the association is composed of representatives of electric-lighting companies, and that its president speaks from the standpoint of the corporations. He stated that the objects of greatest interest to the companies at this time are as follows: (1) Public policy affecting their relations with customers and with public authorities; (2) methods of getting business; (3) economy; this means good engineering, good operating and good service.

The report of the Committee on Progress was read by Mr. T. C. Martin. This gave the total number of central station electric light and power plants as 5,037 in the United States, 396 in Canada and 62 in Mexico. Of the plants in this country, 80% are owned by companies, and the growth of municipal plants was said to be relatively small. Reference was made to developments in electric lamps, including electric filament lamps, mercury vapor lamps and the new Jandus regenerative enclosed flaming-arc lamp recently introduced in England. A notable application of electric power is in the high-pressure fire-protection water supply systems of New York and Brooklyn. The pumps installed at four pumping stations are operated by induction motors aggregating 15,000 HP.

DISTRIBUTION IN SUBURBAN DISTRICTS.—This paper was by Mr. George H. Lukes (Chicago) and explained the situation as follows:

Distribution of electricity for commercial lighting and power in suburban districts is now almost entirely by alternating current at 60 cycles. Small direct-current installations, covering limited areas, combined with alternating current for scattered districts, are still to be

found in places. These are being done away with as fast as local conditions permit. Systems operating at 125 cycles are being rapidly changed over to 60 cycles.

When suburban systems are operated independently of electric railway or direct-current lighting systems, transmission as well as distribution is at 60 cycles. When operated in connection with electric-railway or direct-current lighting systems, the current is frequently transmitted at 25 cycles and converted into 60 cycles for local distribution, but the necessity for operating at two frequencies seems to be rapidly disappearing. Large combination systems, however, cannot be changed over without enormous expense, and must continue to operate at two frequencies unless the development of the 60-cycle business should justify the erection of 60-cycle stations or the installation of a certain proportion of 60-cycle generating equipment in old stations.

The single-phase, three-wire system is ordinarily used for transmission, the voltage ranging from 6,600 to 22,000. The question of single-phase versus three-phase transformers has been thoroughly debated, and the greater factor of safety secured by the use of three transformers instead of one in the relatively small suburban substations seems to warrant their use even at some extra cost. Distribution for commercial lighting and power may be by single-phase, two-phase or three-phase system, the ordinary voltage being approximately 2,200 volts. The four-wire, three-phase system seems to have many advantages over other systems for suburban work.

In the discussion, Mr. F. Osgood (Newark, N. J.) referred to the economy of substantial construction for the transmission line, and pointed out that single-phase motors are not adapted for driving elevators as in starting they affect the line voltage too much. Dr. C. P. Steinmetz (New York) pointed out the necessity of protecting the transmission lines against lightning, as customers find the system very unsatisfactory if the lights are apt to go out every time there is a thunderstorm. As to the transformers on three-phase systems, either one three-phase or three single-phase transformers may be used. Some plants, however, are using an objectionable arrangement with only two transformers. It may work with low-voltage, but is dangerous with high-voltage. Mr. H. B. Gear (Chicago) described a four-wire three-phase system.

The question as to what voltage constitutes a high-tension line was brought up by Mr. H. M. Edwards (New York), who wished to get an expression of opinion for the benefit of the New York Public Service Commission. It was suggested that the association should follow the lead of the underwriters' association in adopting 5,000 volts as the minimum pressure of constant-potential high-tension lines. After some discussion, however, the matter was referred to a committee.

The report of the Committee on Grounding Secondaries was presented by Mr. W. H. Blood, Jr. (Boston). It closed with a resolution to the effect that the National Electrical Code should have a rule requiring the grounding of alternating-current secondary circuits up to 150 volts, and prohibiting the grounding of such circuits carrying over 150 volts. This was adopted at the afternoon session. The report of the Committee on Organization Possibilities was read by Mr. H. L. Doherty (New York), and presented some suggested changes in the organization of the association.

SMALL POWER STATIONS.—Two papers were next presented dealing with the equipment, operation and business of small plants. The first was by Mr. C. Robbins and Mr. J. R. Bibbins.

The practice of to-day is not simply to belt a motor to the line shaft or gear the motor to the machine. It is to give the most minute consideration to the selection of the controller and its location, to the characteristics of the motor and the method of applying it, and to the effect the combination will have on the cost of the product.

The load factor will vary with the kind of service, and may be from 5% to 85% of the connected load. It depends upon the proper selection of motor, the time of operation, and the class of material being worked upon, or the service of the machine. In some classes of work the load-factor will be high if the machines are of the automatic type and the motors are properly selected. The load-factor may be lowered or raised if the motors are not properly proportioned to the work.

The time-factor as well as the average load on the machine must be carefully considered. From these two elements an estimation may be made of the load-time-factor of any installation. In machine tool drive, the time the machine is actually cutting material is but a small percentage of the total; it will vary with the size and type of machine, but rarely will it reach 50% of the total time, and it may fall as low as 10% or even 5%. In these installations the method of control is an important factor, and if time can be saved in the operation the cost of the power service immediately ceases to be the prime consideration, as the labor item is so much greater than the power charge.

As motors are the consuming power device, a better control might be had of the business should the management of the station undertake to sell the motors and install them ready for operation. They would then be able to advise with the consumer concerning the most desirable selection of units and the method of their control.

The second paper, by Mr. P. Spencer and Mr. J. T. Whittlesey, dealt particularly with the necessity for simplicity in design and care in operation of plants of this kind. In the discussion, the character of the load was given most attention. Several speakers thought the companies should take special care that the consumers' motors are not larger than are actually required for the work. Mr. Spencer thought that practically every station of this class is overloaded by motors of unnecessarily high capacity. One speaker pointed out that non-condensing engines are more economical than condensing engines for plants up to about 500 HP. or 600 HP. The theoretical economy in fuel consumption due to condensing is not likely to be obtained with the character of operation and the amount of attention given to the machinery in plants of this size.

The report of the Committee on Uniform Accounting was read by Mr. H. M. Edwards (New York), who explained the work done in co-operation with the Street and Interurban Railway Association and the New York State Public Service Commission. An independent meeting was held at another session for the special benefit of accountants and others interested in uniform accounting and its relation to the regulation of public service companies by state and municipal authorities.

Resolutions in favor of the adoption of an international candle-power standard were adopted at the close of the afternoon session. They were submitted by a joint committee representing the American Institute of Electrical Engineers, the American Gas Institute and the Illuminating Engineering Society.

At the morning session on May 20, the first paper presented was on "Observation on Photometric Precision," by Prof. A. E. Kennelly and Mr. S. E. Whiting, of Harvard University.

LOW-PRESSURE STEAM TURBINES.—This was a very interesting but very long paper by Mr. J. W. Kirkland (Schenectady, N. Y.). Its general character is explained by the following extract:

The low-pressure turbine affords a means of increasing the capacity of existing central stations equipped with reciprocating engines, and at the same time reducing coal consumption. The increased capacity will be secured at a less capital cost than by installing additional high-pressure generating apparatus. These advantages are such as to warrant the serious consideration of low-pressure turbines in connection with plans for increasing the capacity or improving the economy of any engine-driven plant.

The steam turbine is especially efficient when worked in the lower-pressure range (below atmospheric). The combination, therefore, of a high-pressure engine exhausting first into a suitably-proportioned turbine and the latter exhausting into a condenser affords as efficient means of utilizing the available energy of steam as can be designed.

In the discussion, it was pointed out that efficient condensing apparatus and a high vacuum are essential to the economic operation of low-pressure turbines. High-pressure steam turbines can also be improved by raising the vacuum. At the Fisk St. power station in Chicago the vacuum in the new units with sub-base condensers is 29½ ins., as against 27½ ins. in the older units with separate condensers.

GAS ENGINES.—The voluminous report of the Committee on Gas Engines was presented in abstract by Mr. W. C. L. Eglin (Philadelphia), and was accompanied by lantern slides of the illustrations given in the report. It dealt largely with the different makes of high power gas engines now available in this country, with their principal distinguishing features. Producers were also described. Mr. J. R. Bibbins remarked that in American designs of gas engines the tendency has been towards simplification, while in European designs complicated appliances are used in order to obtain very high results in efficiency. Mr. H. F. Freund replied that in aiming at simplicity the makers were apt to lose certain benefits obtained by what were only apparent complications. Other speakers referred to the advances made in adapting producers to low-grade fuels, and also noted the importance of perfecting continuous producers. The economic necessity of employing skilled men to run gas engines and producer gas plants was also explained. A few extracts from the paper are given below:

The question of the relative efficiencies of two-cycle and four-cycle engines has been discussed, and although there are many advocates of the two-cycle system in Europe, in this country the adoption of the four-cycle system is practically unanimous for engines of large sizes. The question is not finally settled, on account of the variety of uses for which the gas engine is available and the comparatively small number of large gas engines in use.

The natural-gas companies have assisted in the development of the gas engine by employing gas engines in their compression stations for forcing the gas over long pipe lines. There are to-day at least 50 of such compressors, varying from 500 to 4,000 HP.

The field for gas engines operated by city illuminating gas is very small, owing to the excessive manufacturing cost and expensive installations necessary for the generation of these gases. There are cases, however, where large engines have been put in under these conditions, but the local circumstances were such that there were other things to be considered besides economy of operation.

In California, for instance, four 5,400 HP. gas-engine units were installed for generating electricity, operating under a gas similar to that being used in the urban distribution. The occasion for this installation was purely local, the gas and electric company being operated under one head, and it was necessary to install stand-by units that could be started on a moment's notice in case of failure of the high-tension transmission line supplied by water-power in mountainous sections of the state. At Atlanta, Ga., a 4,000-HP. engine is operating under ordinary city illuminating gas. This engine was likewise installed as a stand-by unit to start in case of failure of power from water supply, and also as a unit that could be operated one or two hours a day to carry the peak load.

A distinctive feature in the construction of the American type of gas engines as compared with the European design of large sizes, is the universal adoption of the side crank. In Europe the center crank is used. In the valve gear is some form of poppet valve in nearly all cases. With horizontal cylinders, the majority of designs place the exhaust valve at the bottom, and the inlet valve at the top. The cylinders are double-acting, arranged in tandem, and twin-tandem for larger power.

The report of the Committee on Meters was presented by Mr. L. A. Ferguson (Chicago). He outlined the work of the committee and pointed out that meters are of two classes: (1) Those which must be cheap and therefore simple; (2) those in which a high degree of accuracy is required, regardless of cost. Mr. G. E. Crosby (Boston) spoke in regard to the necessity of co-operating with municipal and public-service commissions in order to inform them as to the conditions and thus protect the electric lighting industry against adverse legislation based upon ignorance. Mr. Dow referred to the necessity of testing meters not only in the factory but after they have been set up, in order to check their accuracy under actual conditions of working. One speaker remarked that tests have shown meters to be seriously affected by temperature. A meter that has been found accurate in laboratory or factory tests may therefore be permanently inaccurate when installed at a point having a lower or higher temperature.

The meetings on Thursday were given up almost entirely to the business side of the industry, the papers and discussions dealing with methods of getting business and extending the use of electricity for lighting and power purposes. The only paper of a technical character was that by Mr. V. R. Lansingh on "Illuminating

Engineering as a Commercial Factor." The morning meeting was adjourned directly after being called to order out of respect to the memory of R. C. P. Holmes, of the Commonwealth Electric Co., who was murdered in the streets of Chicago the previous night. This led to an additional session being held by the commercial interests on Friday morning, independent of the regular meeting.

On Friday, May 22, the first paper was on "Receiving Stations Operated from High Tension Lines," by Mr. S. Q. Hayes (Pittsburg). This was followed by the report of the Committee on Protection from Lightning and other Static Disturbances. In the discussion, Dr. Steinmetz referred to the difficulty of assuring the permanence of moisture at grounds. He advocated driving pipes from 3 to 6 ft. deep. At many stations these could be surrounded by earth covered with grass, and this would ensure sufficient moisture. A paper on "The Value of the Care and Maintenance of Meters," by Mr. H. D. King (Hoboken, N. J.) called forth some discussion as to the respective merits of induction meters and commutator meters. Prof. Morgan Brooks showed some interesting tests on the self-synchronizing of alternating-current generators. The instruments were installed on the platform, and the tests were made on a 200-KW., three-phase, 25-cycle motor-driven machine at the Harrison St. power station, about a mile from the hall. A large cable was specially arranged, and the instructions were given by telephone from the platform. The meeting closed with a paper by Mr. W. D'A. Ryan (West Lynn, Mass.) on "Illuminating Engineering for Interior Work," and a brief report from the Committee on Specifications for Street Lighting. This last gave particulars of tests made to determine the relative lighting values of different street arc lamps. The closing meeting and the executive session occupied the afternoon, and the convention was then adjourned.

Mr. W. C. L. Eglin, Electrical Engineer of the Philadelphia Electric Co., was elected President. Mr. John F. Gilchrist, of the Chicago Edison Co., was elected Secretary. The place for the next meeting will be decided later by the executive committee.

AN ORE TRANSFER CAR FOR BLAST FURNACE PLANTS.

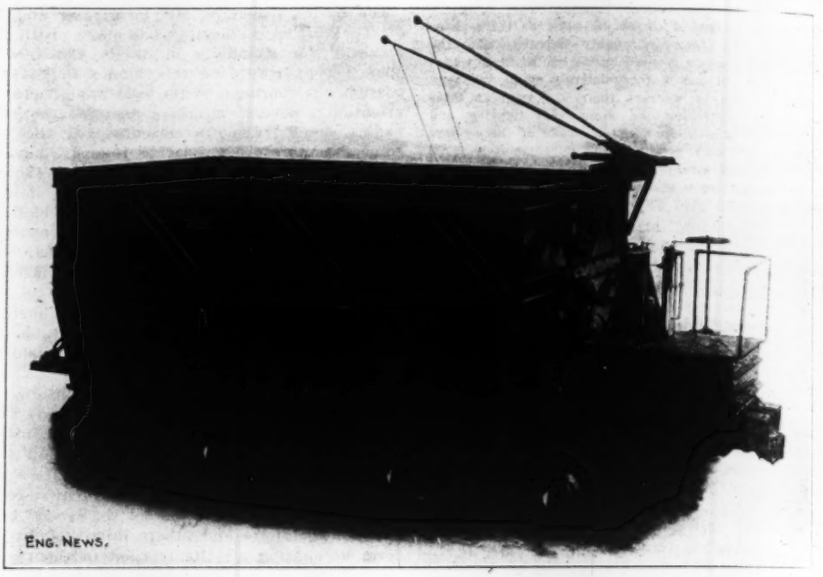
At many blast furnace plants, the ore is carried from the stock yard or storage bins to the charging cars of the furnace inclines or elevators by means of electrically operated motor cars. The accompanying cut illustrates a car of this type built for the Richard Hocksher & Sons Co., of Swedeland, Pa., whose plant has been reconstructed under the direction of Frank C. Roberts & Co., engineers, of Philadelphia. The car was built by the Atlas Car & Mfg. Co., of Cleveland, O., which makes a specialty of cars for industrial plants.

The car is 25 ft. 6 ins. long over the couplers, 10 ft. 6 ins. wide, and 10 ft. 4 ins. high, with a capacity of 1,000 cu. ft. Its load capacity is 125,000 lbs., and the average load is 100,000 lbs. It is mounted on a pair of diamond-frame trucks. The car is of steel construction, heavily braced and reinforced in order to stand the severe work and rough usage to which it will be subjected in service. In some cases the cars are loaded by gravity from overhead bins, but at the Swedeland plant they are loaded from the clamshell bucket of a traveling ore bridge. The cars are built, therefore, to withstand the impact of 6-ton loads falling from a height of 20 ft. A false or removable bottom is used, to allow of easy repair. The bottom slopes from a middle ridge to each side, and the lower part of each side forms a continuous door, hinged at the top and operated by power. To prevent bulging, the door has I-beam stiffeners, while near its lower edge is a heavy reinforcing beam, to the ends of which the operating levers are attached. An inclined plate or apron extends over the truck frames and causes the material dumped to fall clear of the track. The slope of the bottom is over 50°, being made thus steep in order to prevent the load from sticking or lodging, as the material is of a sticky nature (especially in hot weather). In winter, an electric heater is applied to the bottom in order to prevent the material from freezing to the lining of the car.

At one end is the operator's platform, from which are controlled the electric motors, the pneumatic cylinder for operating the doors, the air brakes, and the hand brake. This last is not intended for use in regular service. The door-operating cylinder is mounted vertically beneath the platform, and its piston rod carries a rack which transmits motion by means of gearing to a main shaft which lies in the tunnel formed by the sloping bottom of the car. Arms on the ends of the shaft carry the levers which are attached to the side doors. Turnbuckles on the connections of these rods provide for adjustment for wear, etc., so that the doors will always be closed tightly. In order to give control of the unloading, the cylinder is so arranged that while air under pressure is admitted below the piston, air is also retained as a cushion above the piston, and in this way the doors can be opened or closed either gradually or quickly, as may be desired. The special controlling valve has an indicator to show the position of the doors. The cylinder has hydraulic packing, and both cylinder heads are provided with relief valves.

The electrical equipment of the car is an important feature, in view of the severe and constant service. On each truck is a Westinghouse electric motor, wound for 500-volt direct current and operated from a controller of the reversible enclosed drum type. Two trolley wires and poles are used, one set being for the return current, as ground return is not practicable in the ore yard. Instead of the trolley poles, a pantagraph trolley frame can be used, which adjusts itself automatically at curves and crossings, and in reversing. Under the platform is a motor operating the duplex compressors for the air brakes and the door-handling apparatus. A cut-out switch and automatic controller regulate the air pressure in the reservoir, and the reservoir is made of ample size to supply the door and brake cylinders. The wiring is carefully insulated. All main cables are enclosed in indurated-fiber tubing, and special terminal pieces are applied where the wiring is connected to the motors. The equipment includes lightning arresters, automatic circuit breaker, cut-out switch, resistances, platform lamp and air whistle. Should one of the truck motors be disabled, it can be cut out by the switch, and the car operated by the other motor until repairs can be made. The wheels are ground to exact size. They are mounted on 6½-in. hammered-iron [illegible] journals 5½ × 10 ins.

The car is designed to handle 6,0[illegible] in 10 hours, or at the rate of 600 t[illegible] It carries from 40 to 60 tons per tri[illegible] a round trip every three or four [illegible] can be easily accomplished owing [illegible] power of the motors and the spee[illegible] and closing the doors. The tonnag[illegible] largely governed by the rate of lo[illegible] not in use for transferring ore, th[illegible] utilized as a yard switching [illegible] equipped with M. C. B. couplers a[illegible] ging. The sills and frame are [illegible] enough for this service. It is stated [illegible] can be operated by any careful workman, all levers being marked and having diagrams to show their use.



ELECTRIC ORE TRANSFER CAR FOR THE BLAST FURNACE PLANT OF THE RICHARD HOCKSHER & SONS CO., SWEDELAND, PA.
The Atlas Car & Mfg. Co., Cleveland, O., Builders.

Cars of this type are adapted also to smelting and other industrial plants where large quantities of coarse material have to be transported. Some of them are now being built with an automatic weighing device attached.

SURFACE SUBSIDENCE AT SCRANTON, PA., due to coal-mining operations carried on without due regard for the preservation of superincumbent strata has brought up the question of legislative supervision of underground excavations with a view to limiting them as far as necessary for the safety of Scranton and other interested communities of the anthracite region. The immediate occurrences which have aroused the city officials are the settling of ground amounting to depressions of from six inches to five feet, not only in various parts of the built-up residential district, but in the Borough of Dunmore, through which run the water supply mains to the congested value district. It has been found that a comparatively small subsidence may prove destructive to water and gas mains in its vicinity, adding enormously to fire danger in zones served by connections liable to such interruption. On May 7 the committee on fire prevention of the National Board of Fire Underwriters sent one of its engineers, Mr. R. W. Bogart, Jr., to Scranton to investigate these conditions. The results of his work are summarized in the following recommendations for immediate action:

That where a single break would cut out of service 1,000 ft. or more of mains directly supplying hydrants, additional gates be installed, so that not more than about 500 ft. of mains will be affected. That all future installations of distributing mains be equipped with a sufficient number of gate valves, so located that no single case of accident, breakage or repair to the pipe system in the mercantile and manufacturing districts will necessitate the shutting from service a length of main greater than the side of a single block or a maximum of 500 ft., or in case of other districts lengths not greater than two sides of a single block with a maximum of about 800 ft.

The committee recommends further that an additional supply main to the congested value district be laid by an independent route, and that supervision of mining operations under the city be vested in the mayor and other authorities.

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The paper in this issue on the corrosion of steel pipe lines by Mr. R. H. Gaines will receive the careful study of every engineer interested in hydraulic construction. In the carrying of water long distances under heavy pressure, often a necessity in works for irrigation, power development, mining and municipal water supply, the engineer is confronted with the question what material to use for the pipe.

For nearly 20 years, now, conduits made up of steel plates have been in use, and the experience at Rochester, Portland and other places raises serious doubts as to their durability. As is shown in Mr. Gaines' paper, the corrosion over the whole area of the metal is not at all serious. The difficulty comes through the concentration of the corrosion at certain points where deep pits are made in the plate and finally perforation occurs. It is true that the pipe still remains and the damage can be repaired by digging up and exposing the conduit, cleaning it, patching the perforations and applying a new coat of (supposed) protective covering. This work, however, means heavy expense; and when done, what guarantee have we that a new crop of pits and perforations will not appear and the whole laborious and costly process have to be gone over again?

Why steel should corrode by pitting while wrought iron, almost without exception, corrodes by uniform wasting over its whole surface is one of the puzzling problems which are most difficult of explanation. Whatever the reason may be—whatever the mechanical or chemical or electrical phenomena that cause the pitting—the fact is clear and it is with the facts that the practical engineer is concerned.

The question recurs: When the engineer is obliged to construct a long line of pipe subject to heavy pressure and too large to permit the use of cast iron, what material should he adopt? There are those who will advocate conduits of reinforced concrete, and numerous notable conduits of this material have indeed been constructed. It still remains to be demonstrated, however, whether the concrete can permanently protect from corrosion the reinforcing rods, when hair cracks, due to the stretch of the rods under load, take place in the concrete. Further, where heavy pressure is to be sustained, it is evident, of course, that as much steel must be used in the reinforcing rods as would be required for a complete steel pipe. The only value of the concrete, therefore, is to protect the steel from corrosion.

Other engineers will pin their faith to improved coatings for the steel pipe; and certainly a more durable protection for metal surfaces exposed to corrosion is greatly to be desired. The difficulty comes, as has been often pointed out, in the necessary abrasion of large pipe sections, in shipping, placing in the trench and jointing. However perfect the plate may appear when it leaves the factory, the coating of the final complete conduit always falls far short of perfection.

In view of the experience of Rochester with a wrought-iron conduit and a steel conduit laid side by side, the one attaining a life of 34 years without serious deterioration, and the other requiring extensive repairs at the end of 20 years, engineers will generally look to wrought iron as probably the best solution of the problem. It is true that the engineer desiring to purchase a small quantity of wrought iron finds difficulty in purchasing it, and when he buys it he is beset with the difficulty of determining whether what he receives is really wrought iron or steel. But where a long water conduit is in question, these difficulties ought to disappear.

The amount of material required then becomes so large that the engineer can specify exactly what he desires and have his own inspector on the ground to watch the manufacture of the wrought iron and its rolling into plates. As has been before pointed out in these columns, the development of mechanical puddling during the past few years has removed the old objection to wrought iron. Given sufficient demand for wrought iron, it should be possible to produce it at a cost little, if any, greater than the cost of steel, and where resistance to corrosion is concerned, engineers are generally agreed as to its superiority.

In the current discussion respecting waterway development, it is common to see the old statement put forth that water transportation is necessarily cheaper than rail transportation, and long arguments are based on the assumption that this is a fact.

In another part of this issue Mr. Robert Moore points out that any such statement is misleading. Water transportation *may* be cheaper than carriage by rail or it may be more expensive. There is, of course, no doubt that goods can be carried at less cost from a wharf in Providence to one in New York City by water than by rail; or from a wharf in Chicago to a wharf in Cleveland. But suppose the goods are to be shipped from a factory in Moline to a store in Columbus. Will it be cheaper to load them into a car at Moline, transfer them to the lake steamer at Chicago, and transfer to a car again at Cleveland, or to let the carload of goods go straight through from Moline to Columbus without breaking bulk?

The fact is that the great bulk of the shipments made in this country are between points where water transportation is not and cannot be made available. There is an undoubted field for water transportation on *main avenues of traffic*, and these main avenues are doubtless deserving of improvement; but the idea that the railway network which now covers the country could be to any considerable extent supplanted by a network of waterways is fallacious.

Another statement recently given currency at the Conference on the Conservation of Natural Resources is deserving of investigation before it can be accepted at its face value. The statement is that the coal and iron required to carry a certain amount of freight by rail is several times as great as the amount required to carry the same amount of freight by water. If a natural waterway of reasonable depth and security exists, such, for instance, as the Great Lakes and their connecting channels, this statement is probably true; but it does not follow that it would be true where a large amount of work had to be done to create a waterway by digging a canal or slackwatering a river. In this latter case the coal and iron required to make the waterway and to build all the tools and machinery used in the work must be counted in. Further, the efficiency of the vessel and the railway car would need to be compared. The fact that the car can keep running the year round, while the boat is idle during the winter months, must be considered, and so must the miles run by each in the course of a year. In all matters of this sort it is not safe to rely on off-hand statements. What is wanted is actual facts, and only on expert knowledge of such facts can safe action be based.

FIFTY-FIVE YEARS OF ENGINEERING SERVICE TO SALISBURY, ENGLAND, BY FATHER AND SON.

During an inspection of some of the engineering works of British cities, four years ago, one of the editors of this journal took particular pains to find out how long the various engineers and other municipal officials had been in the employ of their respective towns and cities.

In contrast to general American custom, the rule seemed to be to keep a good man indefinitely, unless he was called to a more important position in some other city.

The most notable instance of a long term of municipal service found during the trip was in the cathedral city of Salisbury, where Mr. Alfred C. Bothams, Assoc. M. Inst. C. E., had recently succeeded his father in the position of city surveyor after his father had been in the employ of the city from 1853 to the time of his death, in 1903. The younger Bothams had, however, been acting city surveyor for the last 15 years of his father's life, had been appointed assistant city surveyor in 1886, and had begun assisting his father in city and in private engineering practice in 1878.

Early in the present year (Jan. 16, 1908; p. 69) in commenting on the election of Mr. Thomas Murray as city engineer of Davenport, Ia., for the "fortieth time," we mentioned the long service of the Bothams at Salisbury. Since then the younger Bothams has resigned his position, in order to give his whole time to private practice as a civil engineer and architect. The record of father and son is so remarkable that we requested Mr. Bothams to give us some particulars of it. This he has kindly done. Of his father's life and services Mr. Bothams writes:

John Champney Bothams was born in 1822, articled in 1839 for four years to Henry Austin (who married a sister of Charles Dickens and met the latter repeatedly as he, my father, lived in the house with the Austins). During the period of his articles Mr. Austin was Honorary Secretary to the Sanitary Association, consisting of Dr. Southwood Smith, Dr. Guy, Mr. Edwin Chadwick and others, which association was the precursor of the General Board of Health of which Mr. Austin was the first Chief Engineer. Mr. Austin was also acting engineer of the London & Blackwall Railway (stationary engines and cables). During the construction of this railway my father was brought into touch with Messrs. G. and R. Stevenson and G. Bidder (the latter known as the "calculating boy") who were the consulting engineers.

In 1845, being out of his articles, Mr. Bothams was engaged by Sir J. Rennie in preparing plans for proposed railways for Captain Moorson, of the London & North Western Railway.

At this period surveying difficulties were very great, owing to the prejudice against railways. Landowners employed men to hold up blankets on poles in front of the level; dogs were let loose for obvious purposes; and occasionally advantage had to be taken of moonlight nights to complete some of the surveys.

In 1852 Mr. Bothams was assistant engineer for the construction of the City of Amsterdam Water-Works, under Joseph Quick. In 1853 he went as resident engineer to the City of Salisbury, under T. W. Rammell, and on the completion of the works of sewerage and water supply he remained as City Surveyor of Salisbury, with private practice as an engineer until his death in 1903.

The sewers constructed in 1853 were made with open joints to admit subsoil water. This arrangement reduced the standing-water level of the city about 3½ ft. and considerably improved the low-level districts. Until this period small canals of running water were provided in nearly every street and the slops were thrown into them and much of the drinking and cooking water was taken from them. Although there had been serious outbreaks of cholera, the promoters of the sewerage and water supply scheme met with much disfavor.

The sewage of the city was discharged into one of the streams of the Avon, untreated, until 1884, when an injunction was obtained to restrain the continuance of the nuisance. A scheme of sewage disposal by precipitation was then carried out by Mr. Bothams for his Council at a cost of £10,000. Disposal by land irrigation was first proposed, on an area at a little distance from the city, but this scheme was not approved by the Local Government Board, owing to its interference with water rights.

It speaks well for both father and son that on the death of the older Bothams, in 1903, the son

was appointed as his successor in the city surveyorship by 23 votes out of 24.

The younger Mr. Bothams has carried out some important works for Salisbury, including waterworks improvements, sewers on the separate plan, and an interesting combination of a refuse destructor, sewage pumping station and sewage purification works. The heat from the refuse destructor is used to lift sewage a few feet to adjoining sewage works, where the sewage passes, successively, through a septic tank, percolating filters and fine-grained finishing filters. Chemical analyses, incubation tests and appearance combine to indicate that a good effluent is produced.

The population of Salisbury is about 22,000. Its area was enlarged in 1904 from 600 to 1,700 acres, resulting in added work for Mr. Bothams.

It is interesting to note that of the foremen or superintendents of works under Mr. Bothams the three having charge of roads, water supply and sewage works, respectively, have been in the employ of the city for from 20 to 28 years, while four of the present laborers were working for the city when Mr. Bothams joined his father, 30 years ago. This certainly speaks well for all concerned.

The British record which, so far as we know, approaches nearest to that of the senior Bothams was but recently brought to public notice by the death of Philip G. Lockwood, early this year. Mr. Lockwood served as borough surveyor of Brighton, England, from 1858 to 1888. In the latter year he was appointed consulting engineer to the town corporation. He resigned in 1904, after a municipal service of about 46 years.

While long terms of municipal service are far less common, number of cities considered, in the United States than in England, yet some of our cities have had the wisdom to profit by the experience and recognize the faithfulness of years of public service. Besides Mr. Murray, of Davenport, already mentioned as having been elected city engineer for the fortieth time, the death in December, 1907, of Col. W. E. Cutshaw, brought out the fact that he had been city engineer of Richmond, Va., for 34 years.

Mr. E. L. Dunbar has served Bay City, Mich., since 1870, for two years as assistant city engineer, and for the past 36 years as superintendent of water-works.

It is in the water-works field, perhaps, that the greatest number of instances of long-continued city service could be found. This might be expected in view of the fact that water-supply systems are the oldest of our public works demanding technical knowledge and experience, and have quite generally been entrusted to boards or commissions which are often quite independent of city councils and frequently remarkably free from politics.

Ten years ago we took the trouble to make a comparison of the tenure of office of superintendents of publicly-owned and privately-owned water-works, as reported in various issues of "The Manual of American Water-Works" (see Eng. News, Nov. 4, 1897). Although the figures showed fewer changes among private than among municipal works, the difference was not so great as we, with a somewhat intimate knowledge of the subject, had supposed. For a period of approximately fifteen years, and a total of 269 water-works, 34% of the private and 23% of the public works retained the same superintendents. Many of such changes as did occur in either class were doubtless caused by death or by change of residence. Many of the superintendents had been in office for years preceding their first appearance in the lists used for our compilation, and not a few are still doing good service.

The foregoing reference has not been made to bring up the vexed question of municipal ownership, but merely to show that, bad as are municipal conditions in many cities of this country, all the officials are not displaced at every election.

There is, however, plenty of opportunity to emulate such records as those of Salisbury and Brighton in England and Davenport, Bay City and Richmond in the United States. It is not, of course, so much the mere length of service of a city official that counts as recognition of the principle that when a competent man has been put in office and gained valuable local experience he should be kept there as long as he serves his city faithfully and ably instead of being turned out at the whim of some faction or party or political boss.

LETTERS TO THE EDITOR.

Railway Building in Brazil.

Sir: The completion of the first line of railway in the State of Para, Brazil, which has been under construction by spurts for the past 26 years, was celebrated on March 28 of this year. This enterprise was a gigantic undertaking in its inception, as it involved many difficulties not easily overcome by the most experienced, much less by amateurs. These facts alone reflect great credit upon its promoters and subsequent builders. It was built by the state and is under state control. Away back in 1870, the first resolution to build this railway from Belem, or Para, on one of the mouths of the Amazon, to Braganca, near the Atlantic coast, on the bay of Marijo, about 100 miles distant, was introduced in the State General Assembly, and since then the project has been fighting a hard battle for existence. Great credit is due the present Governor, Dr. Augusti Montenegro, for his sturdy determination to complete this great work during his term of office. He has built and put into operation considerably over one-half the line since his inauguration. The contractor has completed this year 62 km. (39 mi.). On March 28 the last rails were laid in the city of Braganca, thus connecting Belem, or Para, with that city. The line has been under construction for the last 26 years by different contractors, as well as by state work at intervals.

The present successful completion is also largely due to the worthy engineer, Dr. Hollando Lima, who was one of the contractors, and who has worked with untiring efforts through fever laden swamps and uplands covered with an almost impenetrable forest, to reach the goal marked by the Governor. In this work Dr. Lima was ably assisted by Dr. C. Henry.

The writer paid a visit to the construction work when it was nearing completion, and found a remarkably well constructed and substantial line. The construction was carried out principally by hand work, the only machinery used being small light ½-cu. meter dump cars, which are propelled by hand. This is, no doubt, the beginning of a coast line of railway to Rio Janeiro.

Yours truly,

Toledo, O., May 5, 1908. G. L. Lewis.

The Beneficial Use of Road Drags in Northern Illinois.

Sir: During a visit to northern Illinois last March the writer saw a good illustration of the benefits to ordinary dirt roads from the use of road drags. It was during the usual spring break up and on one section of road the conditions were the same as have always existed, viz., deep ruts holding the water and being cut deeper and deeper by every passing wagon until almost impassible. Teams without loads had difficulty in traveling even at a walk. Another section of road in the same vicinity had been worked with a road drag which preserved the rounded section, filled the ruts and allowed the water to run off. There was no mud on this section and teams were driven at a trot. One of the "drags" seen at the side of the road where it had recently been used was made of two rectangular timbers about 6 × 8 ins. × 8 ft., set on edge, and framed 2 or 3 ft. apart. It was evidently used the same as the split-log drag described in Engineering News of April 2, 1908. The roads described above were ordinary farm roads of black loam, with some clay in places.

Very respectfully,

L. W. Goddard.

U. S. Engineer's Office, Grand Rapids, Mich., May 14, 1908.

The Corps of Engineers and Our Public Works.

Sir: I have read with great interest Mr. Shenehon's letter on The Corps of Engineers and Our Public Works in Engineering News of May 14, and would like to make a few remarks.

To recruit the Corps of Engineers by admitting to it the best of the Assistant Engineers would be a very delicate operation. On the one hand, if the Assistant Engineer be given a place corresponding to his length of service, he will be put over the heads of some of the officers, thus rendering promotion slower and lessening the inducement for young men to enter West Point, besides probably causing heartache and jealousy. For instance, an Assistant Engineer of 20 years' service would probably outrank several of the younger Majors. Suppose that 20 Assistant Engineers of this length of service were given this rela... rank, what chance of promotion would there be fo... the Captains to say nothing of the Lieutenants? T... probabilities are that the ranks of the "graduates," as Mr. Shenehon calls them, would be very shortly and q... considerably increased.

On the other hand, if the Assistant E... neers be offered only the rank of Lieutenant, or in... e cases that of Captain, how many would care to ... e. One solution of the problem would be to co... e by law a body of U. S. Civil Engineers, a title ... dy authorized by law, of which Mr. Meigs is t... olitary but very worthy bearer. Place the membe... of this proposed body on the same footing with ... officers of the Corps of Engineers as regards ex... ve position, responsibility, increase of pay with length ... d efficiency of service and life tenure of office as l... as efficient with no compulsory retirement at an age ... ed, a period when accumulated experience is so valu... e. If they be given no rank, one cause of jealousy would be removed, but advancement for merit should be arranged for.

The provision for life tenure of office would do away with Major Gillette's objection as to politics; the Assistant Engineers would then be, as in days of the Corps of Engineers, "practically beyond political assaults." This tenure of office being the same as that of the Corps of Engineers answers completely your comments on A. R. B.'s letter in Engineering News of March 12.

J. W. T.

[From present indications, of extension in our work of waterway improvements, there is likely to be both work enough for all and glory enough for all the really high-class men in the Engineer Department, both officers of the Corps and civilian assistants. Further, Mr. Shenehon's proposal as we understood was that efficiency and ability and not mere length of service should be the test in selecting men for the higher positions calling for large responsibility in the proposed reorganized corps.—Ed.]

THE COMPARATIVE ECONOMY OF RAILWAY AND WATER TRANSPORTATION.*

The author's statement of the "possibilities of river traffic" as compared with traffic by rail is somewhat misleading.

As a type of river traffic he takes a towboat with a fleet of barges containing 67,000 tons of coal, and as a type of traffic by rail he takes as the load per car 169 tons and the load per train 224.4 tons, or less than 14 carloads, these being the average car and train load of the Frisco Railroad for the past year. From these data he finds that to haul the same amount of coal as was contained on the barges would require 298 trains.

For a fair comparison, however, the conditions for the boat and for the railroad should be equally favorable. A boat with the current in its favor should be compared with a train on a water grade line, and certainly the railroad should be allowed to carry its coal in coal cars, which are now built to carry from 40 to 50 tons and, as every one knows, are almost always overloaded. But on a water grade a locomotive can easily haul trains of from 50 to 60 cars. The St. Louis, Troy & Eastern R. R., a coal road, brings into East St. Louis trains of this size every working day. For this purpose, however, we may assume a train of 50 cars, each loaded with 45 tons. This gives a train load of 2,250 tons, or ten times the load assumed by the author, and the fleet of barges will represent only 29.8 trains instead of 298 trains as stated in the paper.

Coming next to the speed of the boat as compared with that of the car, the author finds the speed of the towboat and barges to be from 75 to 100, or, say, 88 miles per day, and the "speed of freight movement by rail" to be but one-fourth of this amount, or 22 miles per day, basing the latter figure upon a "high authority" not named.

Now it is true that if from the reports of the Interstate Commerce Commission we take the total freight-car mileage of all the roads in the United States for one year and divide it by the total number of freight cars of all classes and then by 365 days, we shall get a quotient of between 23 and 24 miles per day. The average of the four years, 1903, 1904, 1905 and 1906 is 23.98 miles per day, or, say, 1 mile per hour. But this figure is the average movement of all cars, empty and loaded, for all the days of the year, during a large part of which time they are standing idle in shops or on sidings. Therefore, if this figure be used at all, it should be compared only with the average movement for the same time of all boats of all classes, whether they be empty or loaded, in motion or tied up at landings. But if, in our comparison, we take a moving boat, then surely we should take a moving car. And the speed, even of

*A discussion of Mr. J. A. Ockerson's paper on "A Deep Waterway from Lakes to Gulf," Engineering News, May 14, p. 517, by Robert Moore, St. Louis, Mo.

the slowest freight train, can hardly be taken at less than 10 miles per hour, or ten times the speed used by the author.

The facts of this example afford, however, a good illustration of the limitations as well as the possibilities of the two methods of transportation. The coal on the barges referred to was probably and normally brought from the mine to the river in cars,* and the barges can deliver it only at the water's edge, whence it must be again transferred to cars or wagons. The banks of the river are impassable barriers.

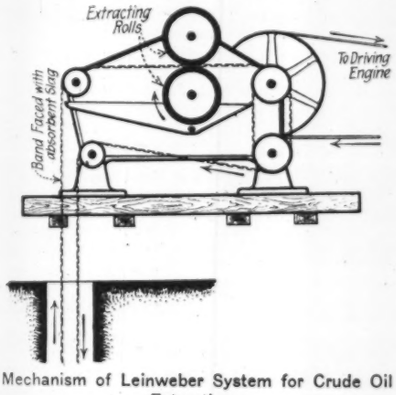
The car, on the other hand, can take the coal from the mine and can deliver it without further handling to any point, whether on river bank or mountain top, that can be reached by a railroad track, and with proper appliances can drop it at the furnace door. To this limitation of the waterway to a single channel, open usually but part of the year, and to the unlimited ability of the railroad to reach any point at any time, is due, more than to anything else, the enormous extension of the railroad which has marked the last fifty years and the relative decline during the same time of traffic by canal and river. That the future will materially change this relation between these two classes of traffic is highly improbable.

A NOVEL SYSTEM FOR RAISING CRUDE OIL FROM WELLS.

A method for raising oil from deep wells has been recently developed and patented by Mr. Bruno Leinweber, of Vienna, Austria.

Briefly, Mr. Leinweber's method consists of lowering an endless, absorbent band into the oil well until the lower end of the loop is immersed in the oil. The band is then run over drums, and the side issuing from the well is squeezed between rollers which wring the oil from it.

The absorbent band is made of flat hemp rope. To make it more absorbent and adhesive, it is faced with a fabric having a long shag or nap.



Mechanism of Leinweber System for Crude Oil Extraction.

In a plant installed for trial at a well in the Kryg oil-field, belonging to the Galician-Carpathian Petroleum Co., Ltd., the band used was about 3 ins. wide and 0.3 in. thick; under test it showed a tensile strength of 9,300 lbs. The shag facing is made about 2½ ins. wide and 0.8 in. thick. Mr. Leinweber states that the hempen band may be used safely for depths up to 1,500 ft., but that bands of steel wire should be used for greater depths. The shag or nap is, of course, what absorbs the oil and brings it to the surface.

The trials of this machine showed that the band, on becoming saturated with oil, runs more smoothly than when dry and adheres better to the driving drum. The band was made in three parts, and the parts were sewed together with ordinary "wax end" on a saddler's sewing machine.

The well at Kryg, at which the apparatus was installed for trial, was 1,700 ft. deep and about 9 ins. in diameter. No steam engine being available, the hoisting mechanism had to be operated with a hand crank; consequently a band speed of only 0.2 meters (about 8 ins.) per second was obtained. In operation the band ran smoothly, and without slippage or tendency to twist; no signs were noticed of rubbing of the band on the sides of the bore hole. No means were employed to card out the fibers of the shag facing after passage of the band through the rollers; this would have produced even better results.

The band brought up a very good yield of oil, of a stiff, jelly-like consistency, which the rollers removed satisfactorily. Of the facing used on the band, about one-half was of low absorptive quality; notwithstanding this the rollers extracted about 415 gals. of oil from each meter of band (about 0.85 lb. per yd.). The fibers of the poor quality of facing lay over the sides of the band, and were thus not entirely freed of oil by the rollers; besides this, considerable oil adhered to the sides of the band itself, which suitable scrapers could have removed.

Allowing for oil carried down again with the band, which could have been recovered with suitable devices (which the isolated location of the well and excessively cold weather made impracticable), the actual available oil brought up by the band was calculated at about 520 gals. per meter (1 lb. per yd.).

At the actual rate of extraction of 0.85 lb. per yd., and the band speed of 8 ins. per second, the amount of oil raised in 1 hr. was about 1,000 gals. This is equivalent to a yield of 24,000 gals. per day, or 760 bbls.

Using the calculated yield of the band with auxiliary collecting devices, and a band speed of 1 meter per second such as could be obtained with steam propulsion, the foregoing figures would be equivalent to a production of 6,200 gals. per hr., or 148,800 gals. (4,720 bbls.) per day of 24 hrs.

ADVANTAGES OF THE LEINWEBER SYSTEM.

Some of the advantages which Mr. Leinweber outlines for his system are briefly as follows:

1. It is adaptable to all depths, even those of 5,000 ft. or greater.
2. It is practicable even for very thick oils containing paraffine, as well as for those containing sand. The denser the oil the larger the output at a given band speed.
3. It may be used in other than vertical bore holes.
4. The driving mechanism is of the most simple sort, much less complicated and requiring less attention than pumps. All mechanism is open and accessible.
5. The band is the only part of the equipment liable to wear. Its wear is, of course, dependent upon the nature of the bore; but as the entire band is in view at some time in its circuit, inspection and necessary repairs are readily made. Repairs may be made simply by cutting out worn sections and stitching in new ones.
6. The machinery can be shipped completely erected and ready for use.

Oil extraction is not the only field of usefulness for which the Leinweber system is available. Salt solutions and acids which attack metallic piping may be raised with it, and it is also adaptable to the drainage of mines where the amount of water is small.

*It is true that on the upper Ohio River and its tributaries there are at present many mines on the river bank. But these mines can only reach the outer edge of the field and must before long be either exhausted or be subject to a long and expensive underground haul that will neutralize their present advantage over the more distant mines.

NOTES FROM ENGINEERING SCHOOLS.

UNIVERSITY OF WISCONSIN.—A regular course for the training of mining engineers, extending over a four-year term of study is to be instituted at the University of Wisconsin. Prof. Edwin C. Holden, of New York, has been appointed to take charge of the department.

CORNELL UNIVERSITY.—A bronze tablet, known as the Thurston Memorial, and presented by the alumni of Sibley College of Mechanical Engineering, will be unveiled in Sibley Hall, Ithaca, on June 16. For the purposes of the ceremony the memorial will be mounted temporarily on a suitable framework in Sibley Hall, but at some future time it will be permanently mounted on the first floor of Sibley Dome on the wall to the right of the main entrance.

This tablet is erected to the memory of Dr. Robert Henry Thurston, the eminent engineer, author and teacher, who was Director of Sibley College from 1885 to the time of his death, in 1903, and to whom is given great credit for the plan and development of professional courses in mechanical engineering, and allied branches, at Cornell University.

The Thurston Memorial is the work of Hermon Atkins MacNeil, the well-known sculptor and designer of important decorative art works for American and foreign expositions, who was for three years instructor in the Department of Drawing in Sibley College.

AN EXPLOSION in the Say Sugar Refinery at Paris, France, in which two persons were killed, 42 burned or otherwise injured and a loss of $100,000 occurred, is reported to have been caused by a spark from a dynamo which fired and exploded an accumulation of sugar dust.

THE COLLAPSE OF A BRIDGE DURING RECONstruction at Detroit, Mich., on May 22, killed two of the workmen and seriously injured three others. The bridge was an old structure which carried Howard St. over the tracks of the Michigan Central R. R., some 50 ft. below, and was in process of repair, with a traveler working on the floor system. It is reported that this traveler in some way upset or rolled off the bridge, carrying with it a portion of the framework of the bridge and the five workmen.

A RAINFALL OF 20 INCHES IN 10 HOURS, according to newspaper reports deluged southern Oklahoma, May 24. The Arkansaw River rose 13 ft. to the highest level attained in 14 years and traffic on all railways in the state was suspended. The Trinity River, near Dallas, Texas, passed the record of 52 ft. made in 1866; it is stated that 4,000 persons were rendered homeless and $1,000,000 of property was destroyed in Texas by the inundation.

A RAILWAY WRECK IN BELGIUM with unusually disastrous results occurred on the morning of May 21. Owing either to the neglect of a switchman, who disappeared after the accident, or to a defect in the switch movement, a fast express bound for Antwerp crashed into the rear of a crowded excursion train which had been sidetracked at Contrich, six miles southeast of the larger city. The sides of the express cars were torn from their fastenings and, the floors collapsing, many of the passengers were thrown to the side of the track with small injury, but the local was completely demolished, few of its occupants escaping alive. The total death roll is reported to number between 40 and 50, and the number of serious injuries at over 70.

DYNAMITERS WRECKED ON MAY 21 THE BRIDGE at Baychester, N. Y., which carries the road from Baychester to Pelham Bay Park over the tracks of the New York, New Haven & Hartford R. R. This bridge is one of the largest now being erected by the railway in its improvement work north of New York City and like all the rest is being built under "open shop" methods. While no evidence to the identity of the wreckers has as yet been found, it is thought that the explosion was the work of certain of the interests whose policy is opposed to the "open shop" and whose dynamiting activities have been reported in the wrecking of several bridges throughout the east within the past two months. Although the contractors at the Baychester bridge had a guard to prevent just such mishaps, the dynamiters managed to get by the watchman some time during the night and affix a time-fuse to an explosive immediately under the base plate of the middle of the four large steel trusses. Luckily the dynamite in exploding did not have as far-reaching effect as the wreckers evidently designed, for the only damage done was to the top of the piers and the framework of the bridge adjoining the pier. It is reported that the estimated damage is about $5,000 and that the opening of the bridge will be delayed about a month.

THE WRECK OF THE FIRST COMMERCIAL AIRship is reported in current press despatches to have occurred at Berkeley, Cal., on May 23. A large dirigible balloon designed by Mr. J. A. Morrell, of San Francisco, making its first trial trip with 16 passengers had ascended to a height of some 300 ft. When the propelling machinery was started the whole machine tilted sharply into the air, rent its gas bag and dropped. The passengers comprised six engine operators, the captain and nine others, either newspaper men or those financially interested in Morrell's schemes. Some of the men jumped before the balloon reached the ground and all who took the venturesome trip were severely hurt. It is expected that a few of the men will die from their injuries. The ascension was made in the presence of some 10,000 people, it is reported, and after the accident the help of scores was necessary to remove the envelope so that the injured men could be removed from the wreckage. This airship is described as having a cigar-shaped gas bag 450 ft. long and 36 ft. in diameter at the center and as being provided with several aeroplanes and wings to assist in steering. Six gasoline engines, of about 30-HP. capacity each, drove 12 propellers.

This whole contrivance was a model of a projected aerial liner, 1,200 ft. long, which was to make the trip from New York to San Francisco in 24 hours and for which many other equally extravagant claims were made. Previous to this disastrous ascent the airship was examined by several expert balloonists who declared that the construction was altogether too flimsy for the size and proposed load.

THE NEW NAVY COLLIER "VESTAL" was successfully launched at the Brooklyn Navy Yard May 19 after the remarkably short construction period of 14 months. This boat is 465 ft. long with 60-ft. beam and has an estimated displacement of 12,585 tons. Her engines will be of triple expansion type with 7,500 I.HP., giving an expected speed of 16 knots.

A STREET RAILWAY ACCIDENT at Philadelphia, May 24, in which four cars were wrecked, two persons killed and 63 injured, is attributed, according to newspaper report, to failure of the brakes. Four cars, filled with Sunday excursionists from White City Park were following one another up the long incline above Bell Mill Road when the fuse of the foremost blew out. It was an open four-wheel car, built with a capacity of 35, but actually carrying 90 passengers; the chain brake gave way, in a few seconds the second car was reached, carried on downward into the third and the three, with interlocked timbers crashed into a fourth car just beginning the ascent.

PERSONALS.

Mr. W. Loring Lee has been appointed City Engineer of Sumter, S. C.

Mr. W. W. Crosby, M. Am. Soc. C. E., was chosen Chief Engineer of the new Highways Commission of Maryland, by Governor Crothers, May 21.

Mr. Clarence A. Bingham, Jun. Am. Soc. C. E., entered upon the duties of his new position as Borough Engineer of Carlisle, Pa., on May 21. He will also conduct a private practice.

Mr. W. Barclay Parsons, M. Am. Soc. C. E., was awarded a Telford gold medal at the annual meeting of the Institution of Civil Engineers of Great Britain on April 28, for a paper contributed to its Transactions.

Mr. Dorsey Ash, Assoc. M. Am. Soc. C. E., and Mr. Frank G. White, Assoc. M. Am. Soc. C. E., have opened a civil and hydraulic engineering office at 112 Market St., San Francisco, Cal., under the firm name of "Ash & White."

Mr. John Berger, M. Am. Soc. C. E., has been appointed resident engineer of the Boston & Albany R. R. (New York Central & Hartford R. R. Co., lessee), in charge of construction west of Springfield, with headquarters at Pittsfield, Mass.

Mr. George H. Clark, M. Am. Soc. C. E., Division Engineer, Public Service Commission for the First District, New York City, has been appointed major and engineer officer on the staff of Brigadier-General George M. Smith, commanding the First Brigade, National Guard of New York.

Obituary.

William P. Boardman, an early builder of street railways, died May 20 at his home in Deshet, S. Dak. The old New York & Harlem Ry., now operated as the Fourth Ave. Ry., of New York City, was constructed under his superintendence.

William Steele, founder and President of the William Steele & Sons Co., engineers and constructors, of Philadelphia, died recently at his residence in Oak Lane, Pa. His firm, established nearly 50 years ago, made a specialty of concrete construction. Mr. Steele was 70 years old and is survived by a widow, five sons, of whom four are associated in the business, and two daughters.

ENGINEERING SOCIETIES.

COMING MEETINGS.

WESTERN RAILWAY CLUB.
May 20. Annual meeting, postponed from May 19, Auditorium Hotel, Chicago, Ill. Secy., Joseph W. Taylor, 390 Old Colony Building, Chicago.

AMERICAN FOUNDRYMEN'S ASSOCIATION.
June 9-11. Annual convention at Toronto, Ont. Secy., Richard Moldenke, Watchung, N. J.

MASTER CAR BUILDERS' ASSOCIATION.
June 17-19. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 22-24. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
June 23-26. Annual convention at Denver, Colo. Secy., C. W. Hunt, 220 West 57th St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
June 23-26. Annual convention at Detroit, Mich. Secy., C. W. Rice, 29 West 39th St., New York City.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.
June 23-26. Annual meeting at Detroit, Mich. (In connection with convention of American Society of Mechanical Engineers.) Secy., A. L. Williston, Pratt Institute, Brooklyn, N. Y.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 23-27. Annual meeting at Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 29-July 2. Annual convention at Atlantic City, N. J. Secy., Ralph W. Pope, 33 West 39th St., N. Y.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
July 24-25. Summer meeting at Niagara Falls, N. Y. Secy., W. M. Mackay, P. O. Box 1818, New York City.

AMERICAN SOCIETY FOR TESTING MATERIALS.—According to the program announced for the eleventh annual meeting of this society, June 23-27, at Atlantic City, there will be two meetings on each of the first four days, and one on the last. An engineering smoker will be held Wednesday evening and an informal dinner is to be enjoyed Friday. The following papers are to be presented: Method of obtaining a truly circular and uniform chill in rolls, T. D. West; The acceptance of stone for use on roads based on standard tests, R. S. Greenman; Fuel investigations, Geological Survey, J. A. Holmes; The structural timbers of the Pacific Coast, R. Thelen; The relative corrosion of steel and wrought iron water pipes, H. M. Howe; Electrolysis and corrosion, A. S. Cushman; Characteristic results of endurance tests on wrought iron, steel and alloys, Henry Souther; Results of tests of steel columns and results of work on the metallurgy of steel, in progress at Watertown Arsenal, J. E. Howard; The influence of the absorptive capacity of bricks upon the adhesion of mortar; A microscopic investigation of broken steel rails; manganese sulphide as a source of danger, Henry Fay; Some results showing the behavior of rails under the drop test, and proposed new form of standard drop testing machine, S. S. Martin; Types of failures in the base of cold-rolled rails, P. H. Dudley; Rail failures—split heads, M. H. Wickhorst; Some notes on the rail situation, E. F. Kenney; Sands—their relation to mortar and concrete, H. S. Spackman and R. W. Lesley; Permeability tests of concrete with the addition of hydrated lime, S. E. Thompson; Some tests of reinforced concrete beams under oft repeated loading, H. C. Berry; An important consideration concerning cement analysis, S. F. Peckham; Formulas for reinforced-concrete beams in the light of experimental data, W. F. Scott; The fireproof qualities of concrete, R. F. Tucker; Shearing values of stone and concrete, H. H. Quimby; Some methods and records used in the laboratory for testing cement and other materials for the subway and elevated railway in Philadelphia, S. A. Brown; The influence of fine grinding on the physical properties of Portland Cement, R. R. Meade; Tests of bond in reinforced concrete beams, M. O. Withey; Cement and concrete work of U. S. Reclamation Service, with notes on disintegration of concrete by action of alkali water, J. Y. Jewett; Certain solubility tests on protective coatings, G. W. Thompson; Analysis of varnishes, P. C. McIlhiney; The use of the extensometer in commercial work, T. D. Lynch; Special features of a recently installed 600,000-lb. Universal Testing Machine, T. Y. Olsen; New forms of pendulum testing machines, T. Y. Olsen; An autographic recorder for commercial tension tests, H. F. Moore; Uniformity in magnetic testing and in the specifications of magnetic properties, C. W. Burrows; Forest Service tests to determine the influence of different methods and rates of loading on the strength and stiffness of timber; a. The purpose and scope of the investigations, McGarvey Cline; b. Analytical discussion of speed-strength relation, H. D. Tieman; Manganese bronze, C. R. Spare; Notes on the desirability of standard specifications for hard-drawn copper wire, J. A. Capp and W. H. Bassett; The structural materials testing laboratories, U. S. Geological Survey; Progress during the year ending June 30, 1908, R. L. Humphrey; Effect of combined stresses on the elastic properties of steel, E. L. Hancock.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the regular meeting of the society on May 20, 1908, Mr. Charles S. Gowen presented a paper on "The Effect of Temperature Changes in Masonry." The paper deals mainly with an account of a long-time series of measurements made, under the direction of the author, upon the widening and closing of several cracks which appeared in the New Croton Dam, a cut stone structure backed with rubble, during and after its construction. These cracks, as is common in large masonry structures, appeared first near the top of the dam and gradually extended in most instances far down the face. By weekly observation and measurement over a period of two years it was determined that the size of the cracks changed appreciably with the change in temperature of the outside air; in fact the curve of the width of the cracks, plotted along weekly readings as abscissas, is practically the same, with some few differences in amplitude, as the curve of temperature plotted on the same horizontal axis.

From these observations the author concluded that the cracks in large masonry structures are due most entirely to variations in atmospheric temperature, although there is a wide field for experimentation to determine the effect, in the making of such cracks, of the stresses set up by the internal temperature changes due to the setting of Portland cement. The d... out of the moisture and the natural shrinking of ...ng concrete are also probably factors in these inte... stresses and should also be made the subject of f... study. A compilation of all of the results on the ... investigation seemed to show a temperatur... of masonry expansion and contraction of 0.... foot per degree. This is about one-half the v... usually agreed upon for this coefficient, but, as was ... in the discussion, the low value is probably ... fact that the outside temperature did not ... the inside of the masonry. In connection ... his experiments Mr. Gowen summarized his con... as follows:

The more compact the masonry the grea... the likelihood of cracks due to changes in tempera...

The localization and extent of such cra... are due primarily to the differences occurring in sec... areas. These arise from carrying on the masonry w... in racks or other unequal elevations of progress in t... masonry, or from changes in section due, for exam... in the case of dams, to buttresses, gate-houses, a... etc., and they develop along straight lines. A... e New Croton Dam, in the curve forming part of t... erflow, no cracks were found during its construct...

If these inequalities in sectional areas re... as they are bound to do in many cases, in a varyi... sectional mass of masonry laid in warm weather or ... mer and particularly if this is unprotected by masonry ... above it later in the season, then the most pronou... cracks are likely to occur.

Temperature changes affect to the greatest ... ent masonry laid in warm weather, and it is important, in order to diminish the extent of temperature cracks to the minimum, to carry such masonry up in fairly level layers and to cover it with as much masonry as possible by steady progress in the colder months.

Changes in section of masonry structures are bound to produce cracks within certain limits, and their extent depends upon the amount of the sectional change and the time of year the masonry is laid.

A dam or wall of uniform section and height carried up uniformly from one end to the other should show temperature cracks at regular intervals, their extent, width, and spacing depending upon the time of year in which the masonry is laid.

That cracks can be avoided to an extent by following rules derived from the above is evident. If uniformity of conditions of building, however, cannot be maintained during construction, cracks can be provided for by vertical slip joints at the proper places, extending through the wall, with proper returns or grooves to break joint, and treated with coal-tar, asphalt, or in other ways that might suggest themselves.

In the discussion which followed the paper Mr. George G. Honness showed several views of two large masonry dams, one at Boonton, N. J., and one at Cross River, N. Y., in which the same cracking was observed as noted in the Croton Dam. In the study of the cracking of these two dams Mr. Honness came to the following conclusions: (1) Racks have small influence upon cracking; (2) no horizontal cracks were observed; (3) there is no uniform distance between vertical cracks; (4) reinforcing to the extent used in the Boonton concrete dam was not sufficient to prevent cracking, and (5) vertical slip joints should be provided in all large masonry dams.

Mr. Thaddeus Merriman, who was connected with the Boonton Dam, gave some few figures on thermophone experiments which he carried on there and which he expects to report more freely at some later date. He said that his observations seemed to show that the interior temperature in a masonry structure varied inversely as the cube root of the distance from the face of the wall. In setting thermophones in masonry it is best to insulate the wires with lead instead of rubber, which latter material rapidly deteriorates under the action of setting concrete.

Mr. William Lowe Brown described to the society the effect of temperature upon the celebrated Assouan Dam across the Nile in Egypt. Although this dam was built under conditions the most adverse to a successful resistance to cracking, it showed very few cracks, aggregating hardly a total width of ¼-in. The masonry was laid in very hot and dry weather in vertical, not horizontal, sections, but the only crack of any consequence occurred above a portion of the foundation where there was an abrupt change in the stone footings. Such a change in the horizontality of footings, in Mr. Brown's opinion, is very often liable to cause cracking.

The program for the fortieth annual convention of the Society to be held at Denver, Colorado, June 23-26, is outlined as follows: Monday, June 22, evening reception at Adams Hotel; Tuesday, June 23, two meetings and a "Seeing Denver" trolley trip; Wednesday, June 24, all day excursion to Arrow; evening, illustrated lecture on "Water Storage and Distribution" by F. H. Newell, M. Am. Soc. C. E., Director U. S. Reclamation Service; Thursday, June 25, two meetings, topics for discussion: "The Maintenance of Macadam and other Roads," opened by Arthur H. Blanchard, Assoc. M. Am. Soc. C. E.; "The Mining of Metals," address by L. D. Ricketts, M. Am. Soc. C. E., and "Irrigation," the principal address on which will be made by George G. Anderson, M. Am. Soc. C. E.; Friday, June 26, All day excursion "Around the Circle" to Fort Collins, going via Boulder and returning via Greely. Evening, reception and ball. The local committee has also tendered a post-convention excursion to Colorado Springs, Pueblo, Cañon City and the Royal Gorge and another to Cripple Creek.